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NUREG-0583

Occupational Radiation Exposure

Eleventh Annual Report 1978

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Eleventh Annual Report 1978

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B. Brooks, S. McDonald, E. Richardson

Licensee Operations Evaluation Branch
Office of Management and Program Analysis
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

OCCUPATIONAL RADIATION EXPOSURE

ELEVENTH ANNUAL REPORT 1978

SUMMARY

This report summarizes the occupational exposure data that is maintained in the U.S. Nuclear Regulatory Commission's Radiation Exposure Information and Reports System (REIRS). This report is published on an annual basis and is available at all NRC public document rooms.

The bulk of the information contained in the report was extracted from annual statistical reports submitted by all NRC licensees subject to the reporting requirement of 10 CFR §20.407. Four categories of licensees - operating nuclear power reactors, fuel fabricators and reprocessors, industrial radiographers, and manufacturers and distributors of specified quantities of byproduct materials - also submit personal identification and exposure information for terminating employees pursuant to 10 CFR §20.408, and some analysis of this data is also presented in this report.

Annual reports were received from 76% of the 8,290 NRC licensees subject to 10 CFR §20.407. Extrapolation of the data to account for that not reported indicated that approximately 287,000 individuals were monitored. Of these, only 139,930 (49%) received measurable doses and incurred a collective dose of 53,710 man-rems. The average dose for all monitored individuals was found to be 0.19 rem, and the average for those individuals having a measurable dose

was 0.38 rem. Approximately 10% of the individuals monitored received doses greater than 0.50 rem; however, they incurred some 76% of the collective dose. Less than 0.1% of those monitored received doses greater than 5 rems.

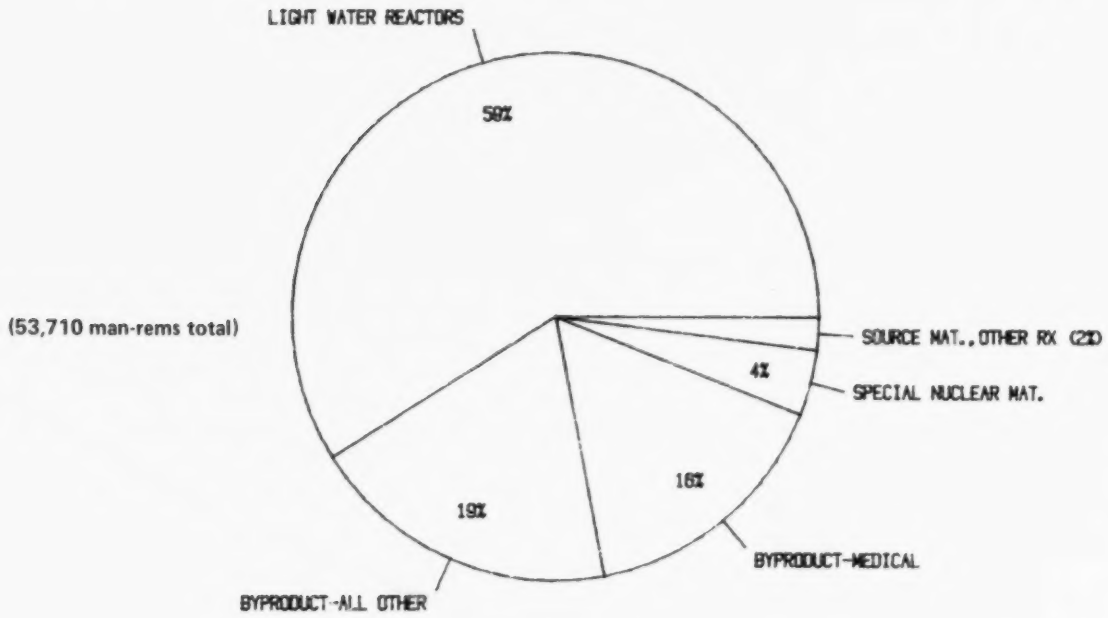
As shown in Figure A, licensed nuclear power facilities monitored 27% of the total number of monitored individuals, and these individuals received about 59% of the collective dose. Extrapolations indicated that medical licensees monitored nearly as many individuals (24%) as did the nuclear power facilities, but the medical workers incurred only 16% of the collective dose. However, all nuclear power facilities are licensed by the NRC; medical institutions in the 26 Agreement States are not licensed by the NRC and are not included in this report. Licensees using NRC-licensed byproduct material for non-medical purposes monitored some 39% of the total number of monitored individuals, and these individuals received 19% of the total collective dose. The remaining types of licensees - research reactors and those using source and special nuclear material for various purposes - monitored only 19% of the 287,000 monitored individuals, and it was calculated that they received about 6% of the collective dose.

Comparisons of the 1978 annual monitoring data with that voluntarily submitted for 1975 were made. Overall, it was found that the extrapolated number of monitored individuals decreased by 39,100 (12%) from the 326,100 individuals monitored in 1975. The extrapolated collective dose, however, increased by 1,870 man-rems (4%) from the 51,840 man-rems estimated for 1975.

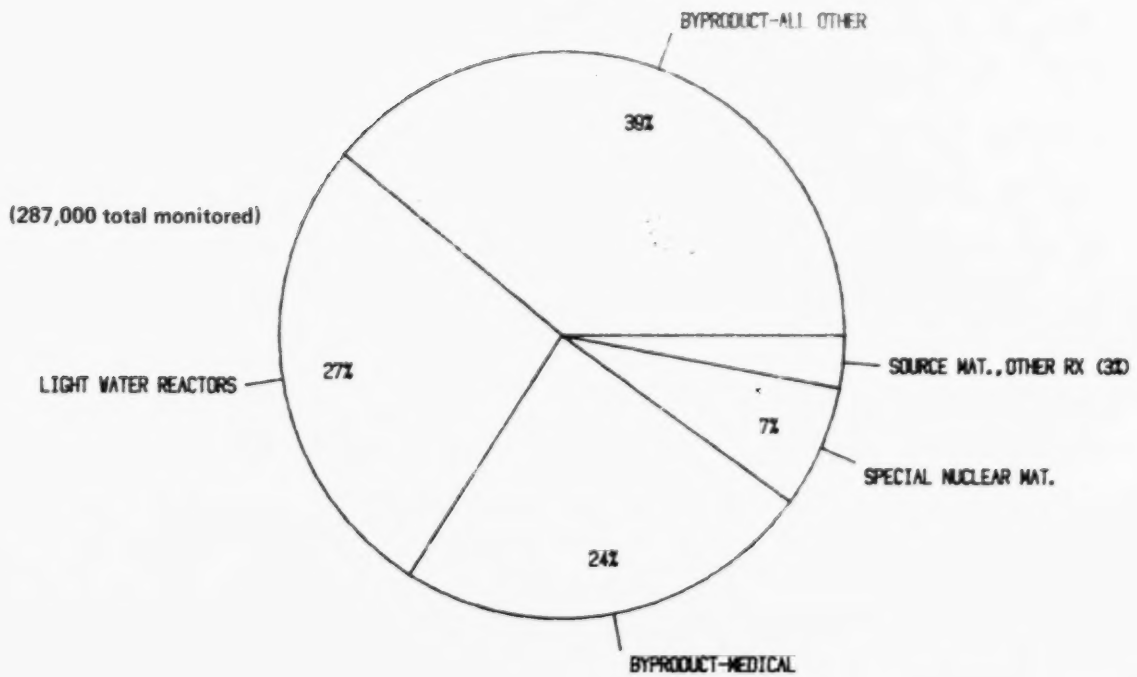
FIGURE A

DISTRIBUTION OF COLLECTIVE DOSE AND MONITORED INDIVIDUALS 1978

DISTRIBUTION OF COLLECTIVE DOSE 1978



DISTRIBUTION OF MONITORED INDIVIDUALS 1978



However, due to the limited data from which the 1975 figures were extrapolated (only 18% of the licensees reported), few conclusions should be drawn from these comparisons. The monitoring data being collected for calendar year 1979 should be more useful in this regard.

Approximately 77,800 termination records with exposure information for 43,200 individuals terminating employment during 1978 were received from the 400 covered NRC licensees and were entered in the Commission's Radiation Exposure Information and Reports System. Examinations of these records revealed that most of these individuals were employed at nuclear power facilities and were between the ages of 20 and 44. Some 1,570 individuals were employed by two or more of the covered NRC licensees during one calendar quarter of 1978. Their average individual dose was found to have declined to 0.46 rem from a high of 1.00 rem in 1972. It was also found that 3,167 individuals were employed at two or more nuclear power facilities during the calendar year 1978. The average measurable dose incurred by these workers was found to be 1.11 rems and 62 more workers were found to have annual doses exceeding 5 rems than was indicated by the compilation of annual statistical reports submitted by nuclear power facilities.

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I. INTRODUCTION

One of the basic purposes of the Atomic Energy Act and the implementing regulations in Title 10, Code of Federal Regulations, Chapter I, Part 20, is to protect the health and safety of the public, including the employees of the licensees conducting operations under those regulations. Among the regulations designed to assure that the standards for protection against radiation set out in 10 CFR Part 20 are met is a requirement that licensees provide individuals likely to be exposed to radiation with devices to monitor their exposure. Each licensee is also required to indefinitely maintain records of the results of such monitoring. However, there was no initial provision that these records, or any summary of them, be transmitted to a central location where the data could be retrieved and analyzed.

On November 4, 1968, the U.S. Atomic Energy Commission (AEC) published an amendment to Part 20 requiring the reporting of certain occupational radiation exposure information to a central repository at AEC Headquarters. This information was required of the four categories* of AEC licensees that were considered to involve the greatest potential for significant occupational doses and of AEC facilities and contractors exempt from licensing. Annual reports for each of the years 1969 through 1973 summarized the data reported

*Commercial nuclear power reactors; industrial radiographers; fuel processors, fabricators, and reprocessors; manufacturers and distributors of specified quantities of byproduct material.

by both AEC licensees and contractors, and were published in six documents designated as WASH-1350-R1 through WASH-1350-R6.

In January 1975, with the separation of the AEC into the Energy Research and Development Administration (ERDA) and the U.S. Nuclear Regulatory Commission (NRC), each agency assumed responsibility for collecting and maintaining occupational radiation exposure information reported by the facilities under its jurisdiction. The annual reports published by the NRC on occupational exposure for calendar year 1974 and subsequent years do not contain information pertaining to ERDA facilities or contractors. Comparable information for facilities and contractors under ERDA, now the Department of Energy (DOE), is collected and published by DOE's Division of Operational and Environmental Safety at Germantown, Maryland.

In May 1975, NRC published a notice of proposed amendment to its regulations that, if adopted, would extend to all specific licensees the requirement for the submission of an annual statistical summary report of personnel monitoring data. Comments on the proposal raised questions regarding the value of the data to be obtained and the burden imposed on licensees. In an attempt to gather the information needed to answer these questions, as well as test the assumption that the four categories of licensees then required to report still involved the greatest potential for significant doses, the NRC requested all specific licensees to voluntarily submit a statistical summary report for calendar year 1975. Analysis of the data presented in NUREG-0419[1] revealed

[1]Cool, W. S., "Occupational Radiation Exposure at NRC-Licensed Facilities 1975," U.S. Nuclear Regulatory Commission, NUREG-0419, March 1978.

that only 18% of the approximately 8,000 licensees responded; therefore, it was decided that all specific licensees would be required to submit an annual report for at least two years.

On September 29, 1978, 10 CFR §20.407 was amended to require that all NRC specific licensees submit annual radiation exposure reports for both calendar years 1978 and 1979. The report was to be a statistical summary report exactly like those that had been required of the previously named four categories of NRC licensees. The requirements in 10 CFR §20.408 for the submission of certain personal and exposure information for individuals terminating employment, however, continue to apply only to these four categories. This document summarizes the annual exposure information that was reported by the 51 types of NRC specific licensees subject to the reporting requirements of §20.407 and the termination data submitted by four categories of licensees. Agreement State licensees are not subject to these reporting requirements and have not been included in this report.

II. LIMITATIONS OF THE DATA

All of the figures compiled in this report relating to exposures and/or doses are based on the results and interpretations of the readings of various types of personnel monitoring devices employed by each licensee. This information obtained from routine personnel monitoring programs is sufficient to characterize the radiation environment in which individuals work, and is used in evaluating the radiation protection program. However, it may not be directly suitable for use in the assessment of risk to the individuals involved.

Monitoring requirements are based, in general, on 10 CFR §20.202 which requires licensees to monitor individuals who receive or are likely to receive a dose in any calendar quarter in excess of 25% of the applicable quarterly limits. For most adults the quarterly limit for the whole body is 1.25 rems, so that 0.312 rem per quarter is the level above which monitoring is required. Depending on the administrative policy of each licensee, persons such as visitors and clerical workers may also be provided with monitoring devices for identification or convenience, although the probability of their being exposed to significant levels of radiation is extremely small. Licensees are given the option of reporting the dose distribution of only those individuals for whom monitoring is required, or the dose distribution of all those for whom monitoring is provided. Many licensees elect to report the latter; however, this may increase the number of individuals that one could consider to be radiation workers. In an effort to account for this, the number of individuals reported as having "no measurable exposures" has been subtracted from the

total number of individuals monitored in order to calculate an average dose per individual receiving a measurable dose, as well as the average dose per monitored individual.

A source of error that is present in the calculation of the annual collective dose (i.e., the summation of each monitored person's whole body dose) incurred by workers is the assumption that the midpoint of the dose range is the mean dose of the individuals reported in each dose range. This allows the collective dose to be calculated without knowing each person's actual annual dose by multiplying the number of individuals in each dose range by the midpoint of the range, and then summing these products. Past experience has shown that the actual mean dose of the individuals reported in each range is less than the assumed arithmetic mean. The collective doses presented in this report may thus be approximately 10% higher.

The average dose per individual, as well as the dose distributions shown for groups of licensees, also could have been affected by the multiple reporting of individuals who were monitored by two or more licensees during the year. Since individuals are not identified in the annual reports, an individual who was monitored by five different licensees would have been counted once on each report. Therefore, when the data were summed to determine the total number of individuals monitored by a group of licensees, this person would be counted as five individuals rather than as one. This could also affect the distribution of doses because the individual has been counted five times in the lower dose ranges rather than one time in the higher range in which his actual accumulated

dose (the sum of his doses incurred at each facility) would have placed him. This source of error has the greatest impact on the data reported by power reactor facilities since they employ many short term workers. Further discussion of this is provided in Section V.C.

Another fact that should be kept in mind before drawing any conclusions from the annual statistical data is that all of the personnel included in the reports may not have been monitored throughout the entire year. Many licensees, such as universities, radiography firms, and nuclear power facilities, may monitor numerous individuals for periods much less than a year. The average doses calculated from this data, therefore, are less than the average dose that an individual would receive if he were involved in that activity for the full year. But it may reflect the dose that a "typical" worker might expect to receive if involvement for the full year is not characteristic of that activity.

III. SUMMARY OF ANNUAL DATA BY PROGRAM CODE

A. Definitions of Program Codes for the Use of Byproduct Materials* and Summary of Data

In order to assign the 6,300 reports submitted by NRC licensees to a type of licensed material and activity, the five-digit number which the NRC assigns to each license to designate the major activity of the licensee was utilized. The NRC uses some 51 program codes to classify the approximately 8,300 licensees that are subject to the reporting requirement of §20.407. Some of these "program codes" narrowly define an activity that corresponds to an industrial segment, such as radiography, while others have such broad definitions that they could simultaneously be part of several industrial segments. This is especially true for the Institutional and Academic program codes which permit the use of radionuclides in both research and instruction/training activities.[2] Also, the NRC may change licensing procedures such that program codes may be added or deleted, or the definition of the program code may change slightly from year to year. In addition, many of the NRC licensees having two or more NRC licenses, or an NRC license and one or more State licenses, provided only one annual report covering all individuals that were monitored. Therefore, the spectrum of radioactive materials and activities encompassed

*Byproduct materials are man-made radioactive materials (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or utilizing special nuclear materials. Although byproduct materials do include activation products from nuclear reactors and plutonium-beryllium neutron sources, they do not include activation products from other neutron sources such as Californium-252 or accelerators.

[2] Centaur Associates, Inc., "An Economic Study of the Radionuclides Industry," February 12, 1980, Contract #NRC-07-78-431.

by licensees in one category may be even broader than is indicated in the descriptions of the program codes.

The submission of a single report for two or more license numbers, each of which may have a different program code, also caused problems in the collation of the data. Since the data on the single report could not be separated by program code, all of the information (number of individuals monitored and their collective dose) was credited to the program code describing the activity and material thought to be the source of the majority of the incurred dose. This methodology probably results in an upward bias in these program codes and a downward bias in the other "secondary" program codes. The bias would have less effect on categories of licensees that encompass most of the primary and secondary program codes, but may be considerable for some categories consisting of a small number of program codes.

In order to facilitate the description of these 51 program codes, they were grouped into 29 functional categories. Following the descriptions of the program codes in each of the 29 categories is a summary of the annual data reported by those types of licensees. A comparison of some of the data with that extracted from annual reports voluntarily submitted by about 18% of the NRC licensees in 1975 is also included. Tables 1, 2, and 3 present the 1978 data in tabular form, and Appendix A presents the 1975 data in the form of certain tables taken from the previously referenced report NUREG-0419[3].

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[3]Ibid, Footnote 1, p. 2.

TABLE 1
DISTRIBUTION OF ANNUAL WHOLE BODY EXPOSURES BY LICENSE PROGRAM CODE
1978

License Category & (Program Code)		Total No. Monitored	EXPOSURE RANGES (REMS) Less Than Measurable	Measurable <0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	5.00-6.00	6.00-7.00	7.00-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	12+
BYPRODUCT MATERIAL CODES																				
Academic																				
Academic-Broad	(01100)	9,263	5,478	2,724	683	212	61	44	51	8	1	1								
Academic-Other	(01200)	8,990	6,913	1,558	299	163	33	9	6	6	1	2								
Medical																				
Institutional-Broad	(02110)	23,843	13,798	6,942	1,772	747	265	140	136	30	9	2	0	1	1						
Institutional-Other	(02120)	32,771	11,319	11,784	4,345	2,692	1,115	548	697	177	45	27	10	6	1	2	1	0	1	1
Private Practice	(02200)	1,015	286	343	195	95	37	20	28	6	1	2	2							
Teletherapy	(02300)	2,077	912	691	258	129	36	20	26	5										
Other Medical	(02400)	951	620	287	29	6	5	2	1	1										
Medical Distribution	(02500)	194	62	71	26	15	14	4	2											
Pacemakers, Instit.	(02600)	0																		
Marketing																				
Marketing-Broad	(03211)	8,849	3,593	2,142	1,118	831	446	246	317	83	28	23	13	8	1					
Marketing-Other	(03212)	5,461	3,638	1,398	227	77	30	17	42	15	11	3	2	1						
Radiography																				
Radiography, one location	(03310)	2,187	1,246	478	195	110	46	32	54	12	9	2	3							
Radiography, multi. locations	(03320)	10,906	5,162	2,595	935	738	431	276	533	150	52	26	3	2	0	0	1	1	0	
Research & Development																				
R & D-Broad	(03610)	11,319	8,958	2,034	150	115	28	6	11	5	11	1								
R & D-Other	(03620)	6,409	4,732	1,486	138	40	9	2	2											
Other Byproduct																				
Well Logging	(03110)	5,044	1,228	1,545	1,045	539	261	140	184	60	24	9	6	1	0	1	0	0	1	
Other Measuring Systems	(03120)	17,553	13,031	3,745	529	150	42	20	24	6	2	2	1	0	0	1				
Nuclear Laundry	(03218)	14	10	0	3	1														
Leak Test	(03220)	129	82	21	11	10	3	1	0	1										
Waste Disposal-Burial	(03231)	18	3	10	3	0	1	0	1											
Waste Disposal-Other	(03232)	314	158	90	17	14	2	8	6	8	10	1								
Power Sources	(03400)	0																		
Irradiator, <10,000 Ci	(03510)	1,272	1,044	184	26	10	3	2	2	1										
Irradiator, >10,000 Ci	(03520)	1,622	1,088	335	122	47	10	8	10	2										
Civil Defense	(03710)	1,833	601	1,097	131	0	2	1	1											

TABLE 1 - Continued
DISTRIBUTION OF ANNUAL WHOLE BODY EXPOSURES BY LICENSE PROGRAM CODE
1978

License Category & (Program Code)		Total No. Monitored	EXPOSURE RANGES (REMS) Less Than Measurable	Measurable <0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	5.00-6.00	6.00-7.00	7.00-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	12+
SOURCE MATERIAL CODES																				
Uranium Mills	(11100)	946	209	277	248	162	23	17	7	2	1									
Uranium Sol. Mines	(11500)	0																		
Other Uranium <150 kg.	(11200)	33	11	21	0	1														
Other Uranium >150 kg.	(11300)	1,439	822	332	117	78	49	18	19	4										
UF_6 Production Plants	(11400)	623	58	274	116	116	27	18	14											
SPECIAL NUCLEAR MATERIAL CODES																				
Fuel Fab. & Processing																				
Plutonium Fuel Fab. & Scrap Recovery	(21110)	680	374	201	77	18	3	2	5											
Plutonium Fuel Fab.	(21120)	1,211	514	311	100	79	45	29	79	41	7	6								
UF_6 Cnvrsn, U Fuel Fab. & Scrap Recovery	(21210)	4,688	2,201	1,256	544	323	180	114	64	6										
Uranium Fuel Fab. & Scrap Recovery	(21220)	242	123	90	21	7	0	1												
Uranium Fuel Fab.	(21230)	4,362	1,942	1,604	408	193	91	41	69	12	1	1								
Fuel Reprocessing	(43110)	122	51	20	15	23	10	0	3											
Other SNM																				
Uranium Other Uses, Incl. R & D	(21240)	386	97	205	43	19	5	2	12	2	0	0	1							
Plutonium Other Uses, Incl. R & D	(21130)	2,290	1,325	737	153	47	22	3	2											
Unencapsulated SNM	(22110)	143	128	2	3	1	1	1	5	2										
Neutron Sources	(22120)	1,641	1,257	327	31	14	6	2	3	0	0	0	1							
Power Sources	(22130)	0																		
Uranium Sources	(22200)	167	148	14	3	0	1	0	0	1										
Other SNM Sources	(22140)	259	218	28	5	4	1	1	2											
Institutional Cardiac Pacemakers	(22160)	30	15	8	1	2	1	0	2	0	1									
Fuel Storage	(23100)	119	65	5	4	5	6	12	21	1										
SNM Storage	(23200)	934	930	4																
REACTOR CODES																				
Research & Test Reactors																				
Test Reactors	(42140)	0																		
Research Reactors	(42150)	2,644	1,780	670	104	27	13	7	23	14	6									
Critical Experiment Facilities	(42160)	0																		
Power Reactors																				
Gas Cooled Power Reactors	(41120)	930	896	34																
Light Water Power Reactors	(41111)	77,523	30,278	17,785	7,002	5,537	3,410	2,507	6,415	2,989	1,079	418	67	26	8	0	0	0	0	2

TABLE 2
ANNUAL EXPOSURE DATA BY LICENSE PROGRAM CODE
1978

License Category & (Program Code)	Fraction (%) of Licenses Reporting	Reports Showing Monitoring was Done	Reports Credited to Other Prog. Code	Total Number of Persons Monitored	Average Individual Dose (REMS)	No. of Persons with Measurable Doses	Average Measurable Dose (REMS)	Total Collective Dose (MAN-REMS)	Average Collective Dose per License (MAN-REMS)	*Extrapolated No. of Persons Monitored	*Extrapolated No. with Measurable Doses	*Extrapolated Collective Dose (MAN-REMS)	**Ratio Ω
BYPRODUCT MATERIAL CODES													
Academic													
Academic-Broad (01100)	33/36 (92%)	27	2	9,263	0.06	3,785	0.13	516	16	10,070	4,110	560	0.64
Academic-Other (01200)	251/352 (71%)	135	17	8,990	0.03	2,077	0.12	256	1	12,660	2,930	360	0.62
Medical													
Institutional-Broad (02110)	90/95 (95%)	87	3	23,843	0.07	10,045	0.15	1,559	17	25,100	10,570	1,640	0.74
Institutional-Other (02120)	1434/1644 (87%)	1,362	22	32,771	0.17	21,452	0.25	5,464	4	37,670	24,660	6,280	1.27
Private Practice (02200)	163/359 (45%)	121	8	1,015	0.20	729	0.28	208	1	2,260	1,620	460	0.72
Teletherapy (02300)	326/443 (74%)	110	209	2,077	0.11	1,165	0.18	220	1	2,810	1,570	300	1.42
Other Medical (02400)	56/70 (80%)	38	7	951	0.03	331	0.09	31	1	1,190	410	40	0.53
Medical Distribution (02500)	34/45 (76%)	12	16	194	0.15	132	0.21	29	1	260	170	40	0.00
Pacemakers, Instit. (02600)	6/9 (67%)	0	4	0	0	0	0.00	0	0	0	0	0	0.00
Marketing													
Marketing-Broad (03211)	46/50 (92%)	40	1	8,849	0.24	5,256	0.40	2,124	46	9,620	5,710	2,310	1.81
Marketing-Other (03212)	183/221 (83%)	131	8	5,461	0.06	1,823	0.18	342	2	6,530	2,200	410	2.00
Radiography													
Radiography, one location (03310)	138/143 (97%)	135	0	2,187	0.15	941	0.34	324	2	2,250	970	330	1.95
Radiography, multi. locations (03320)	199/223 (89%)	190	0	10,906	0.24	5,744	0.46	2,626	13	12,250	6,450	2,950	2.16
Research & Development													
R & D-Broad (03610)	77/77 (100%)	65	4	11,319	0.02	2,361	0.11	266	3	11,319	2,361	266	1.19
R & D-Other (03620)	305/388 (79%)	181	14	6,409	0.02	1,677	0.07	124	<1	8,110	2,120	160	0.06
Other Byproduct													
Well Logging (03110)	62/78 (79%)	50	2	5,044	0.27	3,816	0.36	1,358	22	6,380	4,830	1,720	1.72
Other Measuring Systems (03120)	1852/2555 (71%)	622	71	17,553	0.03	4,522	0.10	461	<1	24,720	6,370	650	0.66
Nuclear Laundry (03218)	3/4 (75%)	3	0	14	0.07	4	0.22	1	<1	20	10	0	0.00
Leak Test (03220)	18/21 (86%)	13	0	129	0.09	47	0.25	12	1	150	50	10	1.03
Waste Disposal-Burial (03231)	1/1 (100%)	1	0	18	0.17	15	0.20	3	3	18	15	3	0.00
Waste Disposal-Other (03232)	12/13 (92%)	8	3	314	0.28	156	0.57	89	7	340	170	100	3.54
Power Sources (03400)	1/1 (100%)	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00
Irradiator, <10,000 Ci (03510)	129/175 (74%)	15	87	1,272	0.02	228	0.11	27	<1	1,720	310	40	0.73
Irradiator, >10,000 Ci (03520)	45/53 (85%)	14	27	1,622	0.05	534	0.16	89	2	1,910	630	100	0.70
Civil Defense (03710)	78/102 (76%)	40	28	1,833	0.04	1,232	0.06	81	1	2,410	1,620	110	0.05

*The extrapolated figures were obtained by dividing the reported number (individuals or collective dose) by the fraction of the licensees reporting.

**The ratio of the fraction of the collective dose due to annual doses greater than 1.5 rems in the observed distribution to the fraction for the UNSCEAR reference distribution. (See Section IV.A., p.)

TABLE 2 - Continued
ANNUAL EXPOSURE DATA BY LICENSE PROGRAM CODE
1978

License Category & (Program Code)		Fraction (%) of Licenses Reporting	Reports Showing Monitoring was Done	Reports Credited to Other Prog. Code	Total Number of Persons Monitored	Average Individual Dose (REMS)	No. of Persons with Measurable Doses	Average Measurable Dose (REMS)	Total Collective Dose (Man-REMS)	Average Collective Dose per License (Man-REMS)	Extrapolated No. of Persons Monitored	*Extrapolated No. with Measurable Doses	*Extrapolated Collective Dose (Man-REMS)	**Ratio Ω
SOURCE MATERIAL CODES														
Uranium Mills	(11100)	15/16 (94%)	9	3	946	0.18	737	0.22	166	11	1,010	780	180	0.41
Uranium Sol. Mines	(11500)	2/2 (100%)	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00
Other Uranium <150 kg.	(11200)	46/58 (79%)	2	17	33	0.03	22	0.06	1	<1	40	30	0	0.00
Other Uranium >150 kg.	(11300)	183/289 (63%)	33	89	1,439	0.10	617	0.24	151	1	2,280	980	240	0.79
UF_6 Production Plants	(11400)	2/2 (100%)	2	0	623	0.21	565	0.23	131	66	623	565	131	0.40
SPECIAL NUCLEAR MATERIAL CODES														
Fuel FAB & Reprocessing														
Plutonium Fuel Fab. & Scrap Recovery	(21110)	3/3 (100%)	3	0	680	0.06	306	0.13	41	14	680	306	41	0.45
Plutonium Fuel Fab.	(21120)	2/3 (67%)	2	0	1,211	0.32	697	0.56	389	194	1,810	1,040	580	2.71
UF_6 Cnvrsn, U Fuel Tab & Scrap Recovery	(21210)	5/5 (100%)	5	0	4,688	0.13	2,487	0.24	602	120	4,688	2,487	602	0.52
Uranium Fuel Fab & Scrap Recovery	(21220)	3/3 (100%)	2	1	242	0.05	119	0.09	12	4	242	119	12	0.00
Uranium Fuel Fab	(21230)	7/8 (88%)	7	0	4,362	0.10	2,420	0.18	458	65	4,960	2,750	520	0.97
Fuel Reprocessing	(43110)	1/1 (100%)	1		122	0.19	71	0.32	23	23	122	71	23	0.48
Other SNM														
Uranium-Other Uses, incl. R&D	(21240)	14/17 (82%)	6	6	386	0.15	289	0.20	58	14	470	350	70	1.66
Plutonium Other Uses, incl. R&D	(21130)	4/6 (67%)	1	0	2,290	0.04	964	0.10	101	25	3,420	1,440	150	0.07
Unencapsulated SNM	(22110)	10/15 (67%)	1	5	143	0.13	15	0.99	15	2	210	20	20	2.89
Neutron Sources	(22120)	189/261 (72%)	35	91	1,641	0.02	384	0.11	43	<1	2,280	530	60	0.89
Power Sources	(22130)	1/3 (33%)	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00
Uranium Sources	(22200)	27/36 (75%)	6	17	167	0.02	19	0.22	4	<1	220	30	10	2.85
Other SNM Sources	(22140)	40/64 (63%)	10	15	259	0.03	41	0.20	8	<1	410	60	10	0.93
Institutional Pacemakers	(22160)	87/172 (51%)	5	49	30	0.27	15	0.53	8	<1	60	30	20	2.93
Fuel Storage	(23100)	3/4 (75%)	2	0	119	0.43	54	0.94	51	17	160	70	70	1.77
SNM Storage Only	(23200)	6/10 (60%)	3	3	934	0.00	4	0.05	0	0	1,560	10	0	0.00
REACTOR CODES														
Research & Test Reactors														
Test Reactors	(42140)	4/4 (100%)	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Research Reactors	(42150)	58/76 (76%)	28	28	2,644	0.06	864	0.19	167	3	3,480	1,140	220	2.18
Critical Experiment Facilities	(42160)	1/4 (25%)	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00
Power Reactors														
Gas Cooled Reactors	(41120)	1/1 (100%)	1	0	930	0.00	24	0.05	2	2	930	24	2	0.00
Light Water Reactors	(41111)	69/69 (100%)	69	0	77,523	0.41	47,245	0.68	31,910	462	77,523	47,245	31,910	2.88
TOTALS		6298/8290 (76%)	3,633	861	253,446	0.20	126,031	0.40	50,550	8	287,000	139,930	53,710	

*The extrapolated figures were obtained by dividing the reported number (individuals or collective dose) by the fraction of the licensees reporting.

**The ratio of the fraction of the collective dose due to annual doses greater than 1.5 rems in the observed distribution to the fraction for the UNSCEAR reference distribution. (See Section IV.A., p.)

TABLE 3
ANNUAL EXPOSURE DATA BY LICENSE TYPE
1978

LICENSE CATEGORY	No. of Monitored Individuals Reported	Workers With Measurable Doses Reported	Collective Dose, Man-rems	Extrapolated Individuals Monitored	Extrapolated Workers With Measurable Doses	Extrapolated Collective Dose, Man-rems	Average Individual Dose, Rems	Average Measurable Dose, Rems
Byproduct Material								
Academic	18,253	5,862	772	22,730	7,040	920	0.04	0.13
Medical	60,851	33,854	7,511	69,290	39,000	8,760	0.13	0.22
Marketing	10,337	5,193	1,615	12,230	6,020	1,870	0.15	0.31
*Manufacturing & Distribution	3,973	1,886	851	3,973	1,886	851	0.21	0.45
Radiography	13,093	6,685	2,950	14,500	7,420	3,280	0.23	0.44
Research & Development	17,728	4,038	390	19,430	4,480	430	0.02	0.10
Other Byproduct Material	27,799	10,554	2,121	37,670	14,010	2,730	0.07	0.19
Total Byproduct Material	152,034	68,072	16,210	179,820	79,860	18,840	0.11	0.24
Source Material Total	3,041	1,941	449	3,950	2,350	550	0.14	0.23
Special Nuclear Material								
Fuel Fab. & Reprocessing	11,305	6,100	1,525	12,500	6,770	1,780	0.14	0.26
Other SNM	5,969	1,785	288	8,790	2,540	410	0.05	0.16
Total SNM	17,274	7,885	1,813	21,290	9,310	2,190	0.10	0.23
Research & Test Reactors	2,644	864	167	3,480	1,140	220	0.06	0.19
Gas Cooled Power Reactors	930	24	2	930	24	2	0.00	0.08
Light Water Power Reactors	77,523	47,245	31,910	77,523	47,245	31,910	0.41	0.67
GRAND TOTALS	253,446	126,031	50,551	287,000	139,930	53,710	0.19	0.38

*Subset of "Marketing" meeting the criteria in §20.408(a)(4) that have previously been required to report.

1. Academic-Broad and Academic-Other Licenses (Program Codes 01100 and 01200)

Academic-Broad and Academic-Other licenses are issued to educational institutions to allow them to use radionuclides for teaching, training, and some research purposes. The Broad licenses are usually issued to the larger institutions where there is often quite a diversity in the utilization of various radionuclides. The kinds and uses of radionuclides may change frequently, even at the same institution. Academic-Other licenses are more limited in scope, and changes in the types and uses of radionuclides may necessitate the NRC's approval and issuance of amendments to the license. Typical uses include tracer studies in biology, chemistry and physics, the demonstration of equipment and gauges, irradiation of materials, carbon-14 dating, calibration of equipment, the identification of substances in compounds, etc.

Reports were credited to a total of 284 license numbers, or 73% of the 388 licenses having an Academic-Broad or an Academic-Other program code. Several institutions having one of these licenses and one or more other types of NRC license, such as irradiator and research reactor licenses, included all monitored individuals on one report. Since the exposure information was not separated by license number, about 25% of the reports may have included exposure resulting from other types of activities. Some 103 reports indicated that personnel monitoring was not required or not provided. Nineteen reports had two or more license numbers and program codes, but all except three of them were credited to one of the two program codes in this group. The 162 reports indicating that monitoring was done were summed to reveal that a total of 18,253 individuals were monitored and that 5,862 of them received measurable

exposures. The highest dose was between 4 and 5 rems, while 98.8% of the doses were less than 0.50 rem. The collective dose was calculated to be 772 man-rems, which yielded an average measurable dose per worker of 0.13 rem. The average annual collective dose per license was estimated to be 3 man-rems.

Extrapolation of this data to account for the number of licensees that did not report indicates that there may be a total of 22,730 individuals being monitored annually, and a collective dose of 920 man-rems being incurred. This can be compared to the figures of 27,000 individuals and 680 man-rems that were extrapolated from the data obtained from the voluntary annual reports for 1975.

2. Institutional-Broad, Institutional-Other, and Teletherapy Licenses (Program Codes 02110, 02120, and 02300)

Institutional-Broad licenses are usually issued to larger medical institutions to allow them to use a wide range of radionuclides in medical research, diagnosis, and therapy. The Institutional-Other licenses are normally issued to a hospital, medical center, or other medical facility to allow the use of radionuclides in well established, more routine, diagnostic and therapeutic procedures. The use of radionuclides in research and diagnosis encompasses *in vivo* and *in vitro* analyses. Therapeutic applications of radionuclides focus on cancer treatment either by drugs containing radionuclides or by beam therapy. Institutions and physicians desiring to use the radiation emitted by a sealed source, usually a fairly large cobalt-60 source, for therapeutic purposes are also issued a separate teletherapy license. These three codes were grouped because more than half of the institutions having a Teletherapy

license also had an Institutional license, and many of them filed one report covering all license numbers.

Reports were credited to a total of 1,850 license numbers, or 85% of the 2,182 licenses having one of these three program codes. Reports for 57 licenses indicated that personnel monitoring was not required or not provided. Some 234 reports had two or more license numbers and program codes, but all except 25 of them were credited to one of the three program codes in this group. The 1,559 reports indicating that monitoring was done were summed to reveal that a total of 58,691 individuals were monitored, and that 32,662 of them received measurable exposures. Other than the accidental overexposure which exceeded 12 rems (see Appendix B) that was reported by a licensee having an Institutional-Other type license, the highest dose was between 11 and 12 rems, while 94% of the doses were less than 0.50 rem. The collective dose was calculated to be 7,243 man-rems which yielded an average measurable dose per worker of 0.22 rem, and an average collective dose per license of about 3 man-rems. It should be noted that most of the licensees in this group also possess and use x-ray machines and radionuclides (such as radium) that are not licensed by the NRC but that do produce and emit ionizing radiation. Many of these licensees reported all monitored individuals, many of whom may have received the major portion of their exposure from non-licensed sources of radiation. Therefore, particularly for these types of licenses, one should not infer that all of the collective dose is due to exposure to NRC-licensed material.

Extrapolation of this data to account for those licensees not reporting indicates there may be a total of 65,580 individuals being monitored, and a

collective dose of 8,220 man-rems being incurred. This can be compared to the figures of 88,800 monitored individuals and 11,900 man-rems that were extrapolated from the data obtained from the voluntary annual reports for 1975.

3. Private Practice Licenses (Program Code 02200)

Private Practice licenses are usually issued to a physician or a group of physicians to allow the use of radionuclides in well established diagnostic and therapeutic procedures in their offices. A total of 163 licenses, or 45% of the 359 licenses assigned a Private Practice program code, were credited with submitting an annual report. Reports for 34 licenses stated that personnel monitoring was not required or not provided, and eight reports having two or more license numbers and program codes were credited to other program codes. The 121 reports indicating that monitoring was done were summed to reveal that a total of 1,015 individuals were monitored and that 729 of them received measurable exposures. The highest dose reported was between 5 and 6 rems, while 91% of the doses were less than 0.50 rem. The collective dose was calculated to be 208 man-rems to yield an average measurable dose per worker of 0.28 rem, and an average collective dose per license of about 1 man-rem. As was the case for Institutional and Teletherapy licensees, many of these licensees probably included individuals exposed to non-NRC licensed sources of radiation in their annual reports.

Extrapolation of this data to account for the number of licensees not reporting indicates that there may be a total of 2,260 individuals being monitored and a cumulative dose of 460 man-rems being incurred. This can be compared to the figures of 4,700 monitored individuals, and 1,320 man-rems

that were extrapolated from the voluntary annual reports submitted for 1975. One reason for the large difference in the data for 1975 and 1978 is the fact that the number of these licenses has decreased by 50%.

4. Other Medical Licenses (Program Code 02400)

Other Medical licenses are issued to individuals or facilities to allow the use of radionuclides in medical activities that were not described above, such as those of veterinarians and clinical labs performing in-vitro analysis. A total of 56, or 80% of the 70 licenses assigned an Other Medical license, were credited with submitting an annual report. Reports for 11 licenses stated that personnel monitoring was not required or not provided, and seven reports having two or more license numbers and program codes were credited to other program codes. The 38 reports indicating that monitoring was done were summed to reveal that a total of 951 individuals were monitored, and that 331 received measurable exposures. The highest dose was between 2 and 3 rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 31 man-rems to yield an average measurable dose per worker of 0.09 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those licensees not reporting indicates that there may be some 1,190 individuals being monitored, and a collective dose of 40 man-rems being incurred. This can be compared to the figures of 2,200 individuals and 280 man-rems that were extrapolated from the data obtained from the voluntary annual reports for 1975. Again, the large difference may be partially due to the fact that the number of these licenses decreased by about 30% between 1975 and 1978.

5. Medical Distribution Licenses (Program Code 02500)

These licenses are issued to nuclear pharmacies to allow them to distribute radiopharmaceuticals to hospitals and physicians. They usually purchase various radioactive materials in bulk from larger firms, prepare individual patient doses, and accumulate them in a central location so that they can be readily distributed.

Reports were credited to a total of 34, or 76% of the 45 licenses assigned a Medical Distribution license. Reports for six licenses stated that monitoring was not required, and 16 reports having two or more license numbers and program codes were credited to other program codes. The 12 reports indicating that personnel were monitored were summed to reveal that a total of 194 individuals were monitored and that 132 of them received measurable doses. The highest dose was between 1 and 2 rems, while 90% of the doses were less than 0.50 rem. The collective dose was calculated to be 29 man-rems, which yielded an average measurable dose per worker of 0.21 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be some 260 individuals being monitored, and a collective dose of 40 man-rems being incurred. This can be compared to the figures of 250 monitored individuals and 20 man-rems that were projected from the 1975 voluntary annual reports.

6. Institutional Byproduct Pacemaker Licenses (Program Code 02600)

These licenses are issued to medical facilities and physicians to allow the surgical implantation of pacemakers that are powered by a device containing byproduct materials. None of this type of pacemaker is presently being manufactured, and there were only nine such licenses in effect during 1978. Six of the nine licenses were credited with submitting an annual report. Two reports stated that monitoring was not required, and the data for the remaining four license numbers were combined with other license numbers having an Institutional-Other program code. Since the devices are constructed such that any individual handling them would receive only minimal exposure, the reports were credited to the other program code.

7. Well Logging Licenses (Program Code 03110)

Well Logging licenses are issued to firms to allow the use of radionuclides for surveying wells to obtain geological information. This testing procedure is primarily used in oil exploration to identify underground oil and water. Annual reports were credited to a total of 62, or 79% of the 78 licenses assigned to a Well Logging program code. Reports for ten licenses stated that personnel monitoring was not required or not provided. The 50 reports indicating monitoring was done were summed to reveal that a total of 5,044 individuals were monitored, and that 3,816 of them received measurable doses. The highest dose was between 11 and 12 rems, while 86% of the doses were less than 0.50 rem. The collective dose was calculated to be 1,358 man-rems to yield an average measurable dose per worker of 0.36 rem, and an average collective dose per license of about 22 man-rems.

Extrapolation of this data to account for those not reporting results in a total of 6,380 individuals being monitored, and a collective dose of 1,720 man-rems being incurred. This can be compared to the figures of 6,800 individuals and 3,000 man-rems that were extrapolated from the 1975 voluntary annual reports.

8. Other Measuring Systems Licenses (Program Code 03120)

These licenses are issued to allow the use of measuring devices that contain radionuclides. This group includes such devices as gas chromatographs and gauges which are frequently used for measuring the level of material, quality control testing in industrial processes, and for soil and construction testing services. In many cases, the licensee is not required to provide personnel radiation monitoring because of the inherent safety of the devices. Frequently, the equipment is serviced and leak tested by the manufacturer or lessor of the equipment.

A total of 1,825 license numbers, or 71% of the 2,555 licenses assigned an Other Measuring Systems program code, were credited with submitting an annual report. Reports for 1,132 licenses stated that personnel monitoring was not required or not provided, and 71 reports having two or more license numbers and program codes were credited to other program codes. The 622 reports indicating that personnel monitoring was done were summed to reveal that a total of 17,553 individuals were monitored, and that 4,522 of them received measurable exposures. The highest dose was between 8 and 9 rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be

461 man-rems, which yielded an average measurable dose per worker of 0.10 rem, and an average collective dose per license that was less than 1 man-rem.

Extrapolation of this data to account for the number of licensees not reporting indicates that there may be some 24,720 individuals being monitored, and a collective dose of 650 man-rems being incurred. This can be compared to the figures of 19,700 monitored individuals and 1,120 man-rems that were extrapolated from the 1975 voluntary annual reports.

9. Marketing-Broad and Marketing-Other Licenses* (Program Codes 03211 and 03212)

Marketing-Broad and Marketing-Other licenses are issued to allow the manufacture and distribution of radionuclides in various forms for a number of diverse purposes. Again, the Broad licenses are issued to the larger facilities having a more comprehensive radiological protection program, and the Other licenses are usually issued to the smaller firms requiring a more restrictive license. Some firms are medical suppliers that process, package or distribute products such as diagnostic test kits, radioactive surgical implants, and tagged radiochemicals for use in medical research, diagnosis and therapy. Other firms are suppliers of industrial radionuclides and are involved in the processing, encapsulation, packaging, and distribution of the radionuclides that they have purchased in bulk quantities from production reactors and cyclotrons. Major products include gamma radiography sources, cobalt irradiation sources, well logging sources, sealed sources for gauges and smoke

*Includes the category "Manufacturers and Distributors" that was previously required to report annually. See Section IV.A.1.

detectors, and radiochemicals for non-medical research. Other firms are involved with the manufacture, assembly and distribution of various products that contain radionuclides.

A subset, usually called "Manufacturers & Distributors," of this group is one of the four categories of licensees that has been required to submit annual reports to the NRC for the past 10 years. This subset consists of approximately 25 licensees that process and distribute large quantities of byproduct material as defined in 10 CFR §20.408(a)(4). Information reported by this subset in 1978 is further discussed in Section IV.A.1. The following figures and analysis are based on reports for all licenses having program codes 03211 or 03212, including the subset.

Reports were credited to a total of 229 license numbers, or 85% of the 271 licenses assigned one of the Marketing program codes. Reports for 49 licenses stated that personnel monitoring was not required or not provided. Nine reports had two or more license numbers and program codes, four of which had one of the two program codes in this group. The 171 reports indicating that monitoring was done were summed to reveal that 14,310 individuals were monitored, and that 7,079 of them received measurable exposures. The highest dose was between 7 and 8 rems, while 91% of the doses were less than 0.50 rem. The collective dose was calculated to be 2,466 man-rems to yield an average measurable exposure per worker of 0.34 rem, and an average collective dose per license of about 11 man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be some 16,200 individuals being monitored and a collective dose of 2,720 man-rems being incurred. This can be compared to the figures of 14,200 individuals and 2,060 man-rems that were extrapolated from the 1975 voluntary annual reports.

10. Nuclear Laundry Licenses (Program Code 03218)

Nuclear Laundry licenses are issued to allow the cleaning of protective clothing contaminated with radioactive material. Firms in this industry often provide nuclear cleaning services as part of a full line of uniform rental or health physics services.

Three of the four licenses assigned a Nuclear Laundry program code were credited with submitting an annual report. Summing the three reports, each of which indicated that monitoring was done, yielded a total of 14 individuals that were monitored, four of whom received measurable doses. All of the doses were less than 0.50 rem, and the collective dose was found to be 1 man-rem. The average annual dose per worker having a measurable exposure was 0.22 rem, and the average collective dose per license was less than 1 man-rem. Extrapolation of this data to account for those licensees not reporting indicates that there may be about 20 individuals being monitored. This is nearly the same as that extrapolated from the 1975 data.

11. Leak Test Licenses (Program Code 03220)

Many facilities own or lease equipment, such as gauges or industrial radiographic cameras, that contains radioactive material and has to be

periodically tested for leakage. This is usually done by swabbing the potentially contaminated surfaces of the device or, in some cases, the surface of the sealed source, and analyzing the swab for radioactive contamination. Leak Test licenses are issued to allow other firms to conduct the leak testing of these devices, and to possess small amounts of radioactive material in order to detect and measure the quantities of materials deposited on the leak test samples.

A total of 18, or 86% of the 21 licenses assigned a Leak Test program code, were credited with submitting an annual report. Reports for five licenses stated that monitoring was not required or not provided. The 13 reports indicating that personnel monitoring was done were summed to reveal that a total of 129 individuals were monitored and that 47 of them received measurable exposures. The highest dose was between 2 and 3 rems, while 96% of the individuals received doses less than 0.50 rem. The collective dose was calculated to be 12 man-rems to yield an average measurable dose per worker of 0.25 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those licensees not reporting indicates that there may be a total of 150 individuals being monitored and a collective dose of about 10 man-rems being incurred. These figures are probably overestimates because two of the larger licensees reporting are involved in activities where exposures may be incurred from non-NRC licensed sources of radiation. Projections from the 1975 annual data indicated only 60 monitored individuals, and a collective dose of 3 man-rems.

12. Waste Disposal Licenses, Burial and Other (Program Codes 03231 and 03232)

Waste Disposal licenses are issued to allow the removal, transportation, storage, or burial of radioactive wastes. There was one firm licensed to operate a burial ground for radioactive wastes, and the thirteen firms having Waste Disposal-Other licenses were authorized to collect packaged waste material, transport it, and temporarily store it before transporting it to an authorized burial ground.

A total of 13, or 93% of the 14 licenses assigned a Waste Disposal program code, were credited with submitting an annual report. One report stated that monitoring was not required, and three reports having two or more license numbers and program codes were credited to other program codes. The nine reports indicating that personnel monitoring was done were summed to reveal that a total of 332 individuals were monitored, and that 171 of them received measurable doses. The highest dose was between 4 and 5 rems, while 94% of the doses were less than 0.50 rem. The collective dose was calculated to be 92 man-rems, which yielded an average dose per worker of 0.28 rem, and an average collective dose per license of about 7 man-rems.

Extrapolation of the data to account for the one licensee not reporting indicates that there may be some 360 individuals being monitored and a collective dose of 100 man-rems being incurred. This can be compared to the figures of 105 monitored individuals and 84 man-rems extrapolated from the 1975 data.

13. Industrial Radiography Licenses, Single and Multiple Locations (Program Codes 03310 and 03320)

These licenses are issued to allow the use of sealed radioactive materials, usually in exposure devices or "cameras", that primarily emit gamma rays for non-destructive testing of pipeline weld joints, steel structures, boilers, aircraft and ship parts, and for other high stress alloy parts. Some firms are licensed to conduct such activities in one location, usually in plant, and others perform radiography at multiple sites in the field.

A total of 337 licenses, or 92% of the 365 licenses assigned a Radiography program code, were credited with submitting an annual report. Twelve reports stated that monitoring was not required or not provided. The 325 reports indicating that monitoring was done were summed to reveal that a total of 13,093 individuals were monitored, and that 6,685 of them received measurable doses. Other than the accidental overexposure of 21.6 rems (see Appendix B), the highest dose was between 10 and 11 rems, while 88% of those monitored had doses less than 0.50 rem. The collective dose was estimated to be 2,950 man-rems, which yielded an average measurable dose per worker of 0.44 rem, and an average collective dose per license of about 9 man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be some 14,500 individuals being monitored and 3,280 man-rems being incurred. Compared to the last few years, this is a considerable increase in the number of monitored individuals, while the collective dose has remained fairly constant. See Section IV.A for further analysis of the information reported by radiography firms.

14. Power Source Licenses (Program Code 03400)

There is one NRC licensee that uses byproduct material to generate heat and power. The U.S. Air Force uses it in a remote weather station in the arctic. No one is required to be monitored.

15. Irradiator Licenses, Less Than or More Than 10,000 Curies (Program Codes 03510 and 03520)

Irradiator licenses are issued to allow the use of large sources of radiation, usually cobalt-60, to produce effects requiring high radiation levels. Primary uses include medical and non-medical research, usually by universities, and industrial uses, such as the sterilization of medical products and drugs, staining of glass, and treating of hard woods, plastics, and semi-conductor materials, etc.

Annual reports were credited to a total of 174 licenses, or 76% of the 228 licenses assigned an Irradiator program code. A majority of the reports (114) were for two or more licenses, and they were credited to other program codes - usually those for medical or academic institutions. Thirty-one reports stated that monitoring was not required or not provided. The remaining 29 reports indicating that monitoring was done were summed to reveal that a total of 2,894 were monitored, and that 762 of them received measurable doses. The highest dose was between 2 and 3 rems, while 97% of the doses were less than 0.50 rem. The collective dose was calculated to be 116 man-rems, which yielded an average dose per worker of 0.15 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be some 3,630 individuals being monitored, and a collective dose of 140 man-rems being incurred. This compares favorably with the number of monitored individuals that was extrapolated from the 1975 data, but the collective dose is nearly three times as large. This could be due to the fact that such a small number (3%) of these licensees submitted a report in 1975.

16. Research and Development Licenses, Broad and Other (Program Codes 03610 and 03620)

These licenses are issued to allow the use of radionuclides in research that is not related to health care or life sciences. There is a large diversity in the kinds of research and uses of radionuclides in non-medical research. Again the Broad licenses are issued to larger facilities having a more comprehensive radiation protection program, where the types of research being conducted may fluctuate rapidly. Typical activities include environmental analysis, food quality studies, aerospace and engineering applications, and product development.

Annual reports were credited to a total of 382, or 82% of the 465 licenses assigned a Research and Development program code. One hundred-eighteen reports stated that monitoring was not required or not provided, and 18 reports having two or more license numbers and program codes were credited to other program codes. The 246 reports indicating that monitoring was done were summed to reveal that 17,728 individuals were monitored, and that 4,038 of them received measurable doses. The highest dose was between 4 and 5 rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be

390 man-rems, which yielded an average measurable dose per worker of 0.10 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be some 19,430 individuals being monitored and 430 man-rems being incurred. These figures are much smaller than those of 34,300 monitored individuals and 980 man-rems extrapolated from the 1975 data which was provided by only 21% of these licensees.

17. Civil Defense Licenses (Program Code 03710)

These licenses are issued to allow the use of radionuclides for training individuals in civil defense activities, such as calibrating and demonstrating the use of radiation survey and monitoring equipment.

A total of 78 licenses, or 76% of the 102 licenses assigned a Civil Defense program code, were credited with submitting an annual report. Ten reports stated that monitoring was not required or not provided. Twenty-eight reports had two or more license numbers, but only nine of them had different program codes and were credited to other program codes. The 40 reports indicating that monitoring was done were summed to reveal that 1,833 individuals were monitored, and that 1,232 of them received measurable doses. The highest dose was between 1 and 2 rems, and 98% of the doses were less than 0.50 rem. The collective dose was calculated to be 81 man-rems, which yielded an average measurable dose per worker of 0.07 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be 2,410 individuals being monitored and 110 man-rems being incurred. These figures are much smaller than the 8,800 monitored individuals and 370 man-rems extrapolated from the 1975 data, which was provided by only 8% of these licensees.

B. Definition of Program Codes for the Use of Source Materials* and Summary of Data

1. Uranium Mill and Mining Licenses (Program Codes 11100 and 11500)

These licenses are issued to allow the extraction of uranium from uranium ore. In milling operations, the ore is crushed, ground to a fine mesh, and chemically treated to convert the uranium to a form called yellowcake. The only mining operation licensed by the the NRC is solution mining, which is *in situ* leaching of ore bodies to extract uranium. Only a very small amount of uranium is mined this way.

A total of 17 licenses, or 94% of the 18 licenses assigned one of these program codes, were credited with submitting an annual report. Three of the reports from mills and both reports from solution mines stated that monitoring was not required or not provided. The nine reports indicating monitoring was done were summed to reveal that 946 individuals were monitored and that 737 of them received measurable doses. The highest dose was between 3 and 4 rems,

*Source materials are materials essential to the production of special nuclear materials. Source materials include uranium (and depleted uranium produced as tailings) and thorium, both of which are naturally occurring and radioactive. Other naturally occurring radioactive materials, such as radium and polonium, are not regulated by the NRC.

while 95% of the doses were less than 0.50 rem. The collective dose was estimated to be 166 man-rems, which yielded an average measurable dose per worker of 0.22 rem, and an average collective dose per license of about 10 man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be some 1,010 individuals being monitored, and 180 man-rems being incurred. The number of individuals is about the same as that extrapolated from the 1975 data, but the collective dose is only half as much.

2. Uranium-Other Licenses, Less Than or More Than 150 Kilograms (Program Codes 11200 and 11300)

The majority of Uranium-Other licenses are issued to allow the use of refined uranium and/or thorium for fabrication, research, and manufacture of consumer products. Included are ceramics, tile, and glassware industries; manufacturers of refractories, uranium shields, fuel elements, and analytical standards; and other uses not specifically classified. A smaller number of these licenses are issued to allow the possession of uranium and/or thorium for uses other than processing or fabrication of any kind, such as distribution and storage. An even smaller number of these licenses are issued to allow the use of uranium in subcritical assemblies.

A total of 229 licenses, or 66% of the 347 licenses assigned one of the programs codes, were credited with submitting an annual report. Reports for 88 of the licenses stated that personnel monitoring was not required or not provided, and 106 of the reports were combined with those for other license

numbers. They were credited to other program codes, usually those of Institutional-Other, Research and Development, or Academic. The 35 reports indicating that monitoring was done were summed to reveal that 1,472 individuals were monitored, and that 639 of them received measurable doses. The highest dose was between 2 and 3 rems, while 94% of the doses were less than 0.50 rem. The collective dose was estimated to be 152 man-rems, which yielded an average measurable dose per worker of 0.24 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those licensees not reporting indicates that there may be 2,320 individuals being monitored, and a collective dose of 240 man-rems being incurred. These values are about half as large as those extrapolated from the 1975 data when only 3% of the licensees reported.

3. Uranium Hexafluoride Production Licenses (Program Code 11400)

These licenses are issued to allow the conversion of yellowcake to uranium hexafluoride (UF_6). There were only two commercial production facilities operating in 1978. These two facilities reported monitoring a total of 623 individuals, 565 of whom received measurable doses. The highest dose was between 1 and 2 rems, while 91% of the doses were less than 0.50 rem. The collective dose was estimated to be 131 man-rems, which yielded an average measurable dose per worker of 0.23 rem, and an average collective dose per license of about 66 man-rems. The number of monitored individuals increased only slightly over that reported in 1975, but the collective dose was nearly twice as large.

C. Definition of Program Codes for the Use of Special Nuclear Materials* and Summary of Data

1. Uranium Hexafluoride Conversion, Uranium and Plutonium Fuel Fabrication and Scrap Recovery Licenses (Program Codes 21110, 21120, 21210, 21220, and 21230)

These licenses are issued to allow the processing and fabrication of reactor fuels. In most uranium facilities, where light water reactor fuels are processed, uranium hexafluoride product enriched in the isotope U-235 is converted to solid uranium dioxide pellets and inserted into zirconium tubes. The tubes are fabricated into fuel assemblies which are shipped to nuclear power plants. On a much smaller scale, fuel assemblies containing plutonium oxide pellets are similarly fabricated and used in reactors for experimental purposes. Some facilities also perform chemical operations to recover the uranium and plutonium from scrap and other off-specifications material.

Annual reports were credited to 20, or 91% of the 22 licenses assigned one of these program codes; all of these indicated that monitoring was done. The reports were summed to reveal that 11,183 individuals were monitored, and that 6,029 of them received measurable doses. The highest dose was between 4 and 5 rems, while 93% of the doses were less than 0.50 rem. The collective dose was calculated to be 1,502 man-rems, which yielded an average measurable dose per worker of 0.25 rem, and an average collective dose per license of about 75 man-rems.

*Special nuclear materials include plutonium, uranium-233, uranium enriched in the isotopes of uranium-235 or uranium-233, and any material artificially enriched in any of these materials.

Extrapolation of this data to account for the two licensees not reporting indicates that there may be 12,480 individuals being monitored and a collective dose of 1,755 man-rems being incurred. The numbers of monitored individuals is slightly less than that reported in 1975, while the collective dose is about half that reported in 1975. These licensees have been required to submit annual reports for the last ten years, and they were previously grouped into the category "Fuel Fabricating & Reprocessing". For further analysis of the data reported in this group, see Section IV.A.

2. Fuel Reprocessing Licenses (Program Code 43110)

Fuel Reprocessing licenses are issued to allow the separation of usable uranium and plutonium from spent nuclear fuel. There is only one licensed commercial facility that has ever reprocessed fuel, and it has been shut down for modification since 1972. The licensee is still storing quantities of radioactive waste at the facility, and they submitted an annual report covering 122 monitored individuals, 71 of whom received measurable doses. The highest dose was between 1 and 2 rems, while 90% of the doses were less than 0.50 rem. The collective dose was calculated to be 23 man-rems which yielded an average measurable dose per worker of 0.32 rem. These values are smaller than those, 209 monitored individuals and 51 man-rems, reported in 1975. Since no fuel reprocessing is being done, this category is usually included with those of the Fuel Fabricators (See Section IV.A).

3. Plutonium or Uranium in Other Uses, Including Research and Development Licenses (Program Codes 21130 and 21240)

These licenses are issued to allow the use of enriched uranium and plutonium for purposes such as academic training and in research and development activities

associated with nuclear fuel. Annual reports were credited to a total of 18, or 78% of the 23 licenses assigned one of these program codes. Reports for five licenses stated that monitoring was not required or not provided. Six other reports were combined with other license numbers and were included in groups having other program codes, usually Academic or Research and Development. The seven remaining reports indicating that monitoring was done were summed to reveal that 2,676 individuals were monitored, and that 1,253 received measurable doses. While the highest dose was between 5 and 6 rems, 98% of the doses were less than 0.50 rem. The collective dose was calculated to be 159 man-rems, to yield an average measurable dose per worker of 0.13 rem, and an average collective dose per license of about 9 man-rems.

Extrapolation of this data to account for those licensees not reporting indicates that there may be 3,890 individuals being monitored and a collective dose of 220 man-rems being incurred. In 1975, only one of the 25 such facilities submitted a report from which it was extrapolated that 3,390 individuals were monitored, and that the collective dose was 60 man-rems.

4. Unencapsulated SNM Licenses (Program Code 22110)

Unencapsulated Special Nuclear Material (SNM) licenses are usually issued to allow the use of small quantities of unencapsulated SNM for purposes such as biological and chemical testing, for calibration sources, etc. Annual reports were credited to a total of ten or 67% of the 15 licenses assigned an Unencapsulated SNM program code. Reports for four licenses stated that monitoring was not required or not provided. Five reports were combined with other

license numbers and were included in groups having other program codes, such as Well Logging, Research and Development, and Research Reactors. The one remaining report stated that 148 individuals were monitored, 15 of whom received measurable exposures. The highest dose was between 2 and 3 rems, while 94% of the doses were less than 0.50 rem. The collective dose was calculated to be 15 man-rems, to yield an average measurable dose per worker of 0.99 rem. This report was from a firm that fabricates neutron sources, an activity that is atypical from the majority of licensees included in this group. Therefore, no extrapolations were made in an effort to account for those not reporting. The extrapolations made from the 1975 data - 2,960 monitored individuals and a collective dose of 310 man-rems - probably were overestimates, because this same firm reported that year also.

5. Neutron Sources, Power Sources, Uranium Sources, and Other Special Nuclear Material Sources Licenses (Program Codes 22120, 22130, 22200, and 22140)

These licenses are issued to allow the use of various quantities of special nuclear material for a number of purposes, such as heat sources in power generators; sources of neutrons for instrument calibration; teaching and demonstration purposes; and well logging and other industrial applications.

Annual Reports were credited to a total of 257, or 71% of the 364 licenses assigned one of these program codes. Reports for 82 of the licenses stated that monitoring was not required or not provided, and 124 reports were combined with other license numbers and were included in groups having different program codes - usually Academic or Research and Development. The remaining 51 reports indicating that monitoring was done were summed to reveal that 2,067 individuals

were monitored, and that 444 of them received measurable doses. The highest dose was between 2 and 3 rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 55 man-rems, which yielded an average measurable dose per worker of 0.12 rem, and an average collective dose per license that was less than 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may have been 2,910 individuals being monitored, and a collective dose of 80 man-rems being incurred. This is much less than the 13,200 monitored individuals and 198 man-rems that were extrapolated from the reports voluntarily submitted by only 6% of these licensees in 1975.

6. Institutional Cardiac Pacemaker Licenses (Program Code 22160)

These licenses are issued to medical facilities and physicians to allow the surgical implantation of pacemakers that are powered by a device containing special nuclear material. Very few new nuclear pacemakers are currently being manufactured.

A total of 87, or 51% of the 172 licenses assigned this program code, were credited with submitting an annual report. Reports for 33 licenses stated that monitoring was not required or not provided, and 49 reports were combined with another license number which had a different program code. In nearly every case these reports were credited to one of the Institutional program codes. The five remaining reports indicating that monitoring was done were summed to reveal that 30 individuals were monitored, and that 15 of them received measurable doses. The highest dose was between 3 and 4 rems, while

87% of the doses were less than 0.50 rem. The collective dose was calculated to be 8 man-rems, which yielded an average measurable dose per worker of 0.53 rem, and an average collective dose per license that was less than 1 man-rem.

Extrapolation of this data to account for those not reporting results in 60 monitored individuals and a collective dose of 16 man-rems. No reports were credited to this program code in 1975, and it is doubtful that any significant doses were received from the SNM pacemakers in 1978. Many of the individuals involved with pacemakers are cardiologists who also work with x-ray machines during cardiac catheterization and fluoroscopy procedures. They would receive the majority of their doses from these non-NRC licensed sources of radiation.

7. Fuel Storage and SNM Storage Only Licenses (Program Codes 23100 and 23200)

These licenses are issued to allow the storage of items containing special nuclear material, such as new or spent reactor fuel elements, and sealed sources not being used. Operating nuclear reactors do not require such a license to store their own fuel.

Annual reports were credited to three of the four Fuel Storage licenses and six of the ten SNM Storage Only licenses. One of the Fuel Storage licensees stated that monitoring was not required or not provided, and three reports from SNM Storage Only licensees were combined with those for other license numbers. The two Fuel Storage reports stating that monitoring was done were

summed to reveal that 119 individuals were monitored and that 54 of them received measurable doses. The highest dose was between 2 and 3 rems, while 66% of the doses were less than 0.50 rem. The collective dose was calculated to be 51 man-rems, which yielded an average measurable dose per worker of 0.94 rem, and an average collective dose per license of about 17 man-rems. Extrapolation of this data to account for those not reporting results in 160 monitored individuals and a collective dose of 70 man-rems. These values are consistent with those of 130 monitored individuals and 90 man-rems which were extrapolated from the 1975 data.

The data reported by the three SNM Storage Only licensees stating that monitoring was provided is quite different from that of the Fuel Storage licensees. These reports revealed that some 934 individuals were monitored, and that only four individuals received measurable doses - all of which were less than 0.10 rem. One reason for the difference in the doses reported by these licensees may be that some of the employees of the Fuel Storage licensees also assist in the removal and transfer of the fuel which could result in higher doses. Extrapolation of the SNM Storage Only data to account for those not reporting results in 1,560 monitored individuals with no one receiving a measurable dose. The 1975 data indicated only eight monitored individuals and a collective dose of less than 1 man-rem. One reason for the large increase in the number of monitored individuals between the years of 1975 and 1978 would be that the number of these licenses increased from two to ten.

8. Water Cooled Power Reactor Licenses (Program Code 41111)

These licenses are issued to utilities to allow them to use special nuclear material in a reactor to produce heat to generate electricity to be sold to consumers. There are two types of reactors having this program code - pressurized water reactors and boiling water reactors - each of which uses water as the primary coolant.

Reports were received from all 69 of the commercially operating power reactors. Facilities having more than one licensed reactor at one site submitted one report covering all reactors at that site. They all indicated that monitoring was done and were summed to reveal that a total of 77,523 individuals were monitored, some 47,245 of whom received measurable doses. Other than the two accidental overexposures reported by Trojan (see Appendix B) the highest dose was between 7 and 8 rems, while 78% of the doses were less than 0.50 rem. The collective dose was calculated to be 31,910 man-rems, which yielded an average measurable dose per worker of 0.68 rem, and an average collective dose per reactor of 462 man-rems. See Section IV.A for further analysis of the data reported by power reactors.

9. Gas Cooled Power Reactor Licenses (Program Code 41120)

These licenses are issued to utilities to allow the use of special nuclear material in a reactor to produce heat to generate electricity to be sold to consumers. Helium is used as the primary coolant. Fort St. Vrain near Greeley, Colorado, is the only such reactor in operation in the U.S. In 1978 they monitored 930 individuals, only 34 of whom received measurable doses, and all

of the doses were less than 0.10 rem. Although the utility did not declare the plant to be in commercial operation until July 1979, the following table displays the plant's exposure experience for the five years 1974 through 1978.

TABLE 4
ANNUAL DOSES AT FORT ST. VRAIN
1974-1978

Year	No. of Individuals with Annual Doses in Ranges (Rems)			Total No. of Individuals Monitored	Annual Collective Dose (Man-Rems)	Gross Electrical MW-Yrs. Generated	Average Measurable Dose Per Worker (Rems)
	No Measurable Dose	Measurable <0.10	0.10-0.25				
1974	1,597	63	1	1,661	3.3	0.0	0.05
1975	1,263	0	0	1,263	0.0	0.0	0.00
1976	1,362	25	0	1,387	1.3	2.8	0.05
1977	946	55	1	1,002	2.9	29.8	0.05
1978	896	34	0	930	1.7	75.7	0.05

10. Test, Research, and Critical Reactor Licenses (Program Codes 42140, 42150, and 42160)

These licenses are issued to allow the use of special nuclear material in various types of reactors for purposes other than to commercially produce electrical power. The majority of them are operated by universities. The test and research reactors are available to perform experiments to study radiation effects, and to produce radionuclides to be used in research and by the radiopharmaceutical industry. Critical reactors are fueled facilities that can achieve criticality so that experiments using various types and configurations of fuel and different moderators can be performed.

A total of 63 licenses, or 75% of the 84 licenses assigned one of these program codes, were credited with submitting an annual report. Two reports

stated that monitoring was not required, and 33 reports were combined with other license numbers having different program codes. These were usually credited to the Academic or the Research and Development program codes. The 28 reports indicating that personnel monitoring was done were all from Research Reactor licensees, and they were summed to reveal that 2,644 individuals were monitored, and that 864 of them received measurable doses. The highest dose was between 3 and 4 rems, while 98% of the doses were less than 0.50 rem. The collective dose was calculated to be 167 man-rems, which yielded an average measurable dose per worker of 0.19 rem, and an average collective dose per license of about 3 man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be 3,480 individuals being monitored and a collective dose of 220 man-rems being incurred. The number of monitored individuals is about the same as that extrapolated from the 1975 data, but the collective dose is 200 man-rems less.

IV. FURTHER ANALYSIS OF THE ANNUAL EXPOSURE DATA

A. Annual Exposure Data for Four Categories* of Licensees

This section presents and analyzes the annual exposure data submitted by the four categories of licensees that have been required to report such data since 1968 in a manner similar to that found in previous occupational radiation exposure reports. This should facilitate the comparison of the 1978 data with that of data for other years and the observation of any trends that might exist.

1. Composite Annual Dose Distributions

Table 5 is a compilation of the statistical reports submitted by four categories of NRC licensees for calendar year 1978. It shows the number of individuals that incurred a cumulative whole body dose that fell within one of the 18 dose ranges, and the percentage that this number is of the total number monitored. It also shows the collective dose calculated to have been received by these individuals. The table reveals that 42% of the 105,893 individuals monitored during 1978 received exposures that were too small to be detected by personnel radiation monitoring devices and that less than one percent of the individuals incurred doses that exceeded 5 rems. Manufacturers and Distributors had the highest percentage of workers receiving doses in excess of 5 rems, but like the Fuel Fabricators and Reprocessors, they reported no doses in excess of 12 rems.

*Commercial nuclear power reactors; industrial radiographers; fuel processors, fabricators and reprocessors; manufacturers and distributors of specified quantities of byproduct material.

TABLE 5

DISTRIBUTION OF ANNUAL WHOLE BODY DOSE BY LICENSE CATEGORY

1978

CATEGORY OF NRC LICENSE	Number of Individuals with Wholes Body Doses in the Following Ranges (Rems)																		Totals
	No Measurable Exposure	Measurable <0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	5.0-6.0	6.0-7.0	7.0-8.0	8.0-9.0	9.0-10.0	10.0-11.0	11.0-12.0	>12.0	
*POWER REACTORS																			
No. of Individuals	30,278	17,785	7,002	5,537	3,410	2,507	6,415	2,989	1,079	418	67	26	8	0	0	0	0	2	77,523
Percent in Range	39%	23%	9%	7%	4%	3%	8%	4%	1%	1%					1%				100%
No. of Man-rems	0	889	1,225	2,076	2,131	2,194	9,623	7,472	3,777	1,881	369	169	60	0	0	0	0	44	31,910
Percent in Range	0%	3%	4%	7%	7%	7%	30%	22%	12%	6%	1%				1%				100%
RADIOGRAPHY																			
No. of Individuals	6,408	3,073	1,130	848	477	308	587	162	61	28	6	2	0	0	1	1		1	13,093
Percent in Range	49%	23%	9%	6%	4%	2%	4%	1%					2%						100%
No. of Man-rems	0	154	198	318	298	270	880	405	213	126	33	13	0	0	10	10		22	2,950
Percent in Range	0%	5%	7%	11%	10%	9%	30%	14%	7%	4%	1%				2%				100%
FUEL FABRICATION & REPROCESSING																			
No. of Individuals	5,205	3,482	1,165	643	329	187	220	59	8	7									11,305
Percent in Range	46%	31%	10%	6%	3%	2%						2%							100%
No. of Man-rems	0	174	204	241	206	164	330	147	28	31									1,525
Percent in Range	0%	11%	13%	16%	14%	11%	22%	10%				3%							100%
MANUFACTURING & DISTRIBUTION																			
No. of Individuals	2,087	1,108	289	135	81	57	99	46	24	23	14	9	1						3,973
Percent in Range	53%	28%	7%	3%	2%	1%	2%	1%						3%					100%
No. of Man-rems	0	55	51	51	51	50	148	115	84	103	77	58	8						851
Percent in Range	0%	6%	6%	6%	6%	6%	17%	14%	10%	12%	9%	7%	1%						100%
TOTALS																			
No. of Individuals	43,978	25,448	9,586	7,163	4,297	3,059	7,321	3,256	1,172	476	87	37	9	0	1	1		3	105,893
Percent in Range	42%	24%	9%	7%	4%	3%	7%	3%					1%						100%
No. of Man-rems	0	1,272	1,678	2,686	2,686	2,678	10,981	8,139	4,102	2,141	479	240	68	0	10	10	0	44	37,214
Percent in Range	0%	3%	5%	7%	7%	7%	30%	22%	11%	6%	1%				1%				100%

*Includes all reactors that reported although all of them may not have been in commercial operation for a full year.

**A subject of "Marketing" that includes the 27 licensees meeting the criteria in 20.408 that have previously been required to report.

It should be pointed out that very few of the annual exposures that exceed 5 rems are classified as personnel overexposures. Although 1.25 rems is the quarterly limit set forth in paragraph (a) of 10 CFR §20.101, paragraph (b) permits licensees, under certain conditions, to allow a worker to receive a whole body dose of 3 rems per calendar quarter (up to 12 rems annually). The conditions are that (1) the licensee must have determined and recorded the worker's prior accumulated occupational dose to the whole body, and that (2) the worker's whole body dose when added to his accumulated occupational dose does not exceed 5(N-18) rems where "N" equals the individual's age in years. Although there is no annual limit, annual exposures that exceed 12 rems indicate that an overexposure has occurred. Any quarterly whole body exposure in excess of the applicable quarterly limits are considered overexposures and must be reported. A discussion of various types of overexposures that may occur is given in Section VI.

A summary of the annual whole body exposures reported to the Commission by the four categories of NRC licensees required to submit reports during the past ten years is presented in Table 6. One can see that about 95% of the exposures have consistently remained less than 2 rems, and that the number of individuals receiving an annual dose in excess of 5 rems has decreased from one-half of one percent of the total number of individuals monitored in 1975 to one-tenth of one percent in 1978.

Table 7 summarizes the annual exposure data reported by four categories of licensees for the years 1973 through 1978. Primarily reflecting the growth in the number of workers employed at the increasing number of nuclear power

TABLE 6

SUMMARY OF ANNUAL WHOLE BODY EXPOSURES
FOR FOUR CATEGORIES OF LICENSEES

1968–1978

Year	Total Number Individuals Monitored	Percent of Individuals With Doses < 2 Rems	Percent of Individuals With Doses > 5 Rems	Number of Individuals With Doses > 12 Rems
1968	36,836	97.2%	0.5%	3
1969	31,176	96.5%	0.5%	7
1970	36,164	96.1%	0.6%	0
1971	36,311	95.3%	0.7%	1
1972	44,690	95.7%	0.5%	8
1973	67,862	95.0%	0.5%	1
1974	85,097	96.4%	0.3%	1
1975	78,713	94.8%	0.5%	1
1976	92,773	95.0%	0.4%	3
1977	98,212	94.5%	0.3%	1
1978	105,893	95.2%	0.1%	3

TABLE 7

ANNUAL EXPOSURE DATA FOR FOUR CATEGORIES OF LICENSEES

1973-1978

Category of NRC License	Calendar Year	Number of Licensees Reporting	Total No. Individuals Monitored	No. Individuals With Measurable Exposure	Total Collective Dose Man-rems	Average Dose (Rems) Per Individual (Based on Total Monitored)	Average Dose (Rems) Per Worker (Based on Measureable Exposure)	Collective Dose Per License, Man-rems
*Commercial Power Reactors	1978	69	77,523	47,245	31,910	0.41	0.67	462
	1977	65	71,904	44,233	32,731	0.46	0.74	504
	1976	62	66,800	36,715	26,555	0.40	0.72	428
	1975	54	54,763	28,034	21,270	0.39	0.76	394
	1974	53	62,044	21,904	14,083	0.23	0.64	266
	1973	41	44,795	16,558	14,337	0.32	0.87	350
Industrial Radiography	1978	337	13,093	6,685	2,950	0.23	0.44	9
	1977	339	10,569	6,197	3,159	0.30	0.51	9
	1976	321	11,245	6,222	3,629	0.32	0.58	11
	1975	291	9,178	4,693	2,796	0.30	0.60	10
	1974	319	8,792	4,943	2,938	0.33	0.59	9
	1973	341	8,206	5,328	3,354	0.41	0.63	10
Fuel Fabrication and Re-processing	1978	20	11,305	6,100	1,525	0.13	0.25	76
	1977	21	11,496	7,004	1,725	0.15	0.25	82
	1976	24	11,227	5,285	1,830	0.16	0.35	76
	1975	24	11,614	5,602	3,175	0.27	0.57	132
	1974	26	11,064	4,728	2,836	0.26	0.60	109
	1973	27	10,610	5,056	2,400	0.23	0.47	89
Manufacturing and Distribution	1978	27	3,973	1,886	851	0.21	0.45	32
	1977	30	4,243	2,459	1,329	0.31	0.54	44
	1976	24	3,501	1,976	1,226	0.35	0.62	51
	1975	19	3,367	1,859	1,188	0.35	0.64	63
	1974	24	3,340	1,827	1,050	0.31	0.57	44
	1973	34	4,251	1,925	1,177	0.28	0.61	35
Grand Totals and Averages	1978	454	105,894	61,916	37,236	0.35	0.60	82
	1977	455	98,212	59,893	38,944	0.40	0.65	96
	1976	428	92,773	50,198	33,240	0.36	0.66	78
	1975	388	78,922	40,188	28,429	0.36	0.71	73
	1974	422	85,240	33,402	20,907	0.25	0.63	50
	1973	443	67,862	28,867	21,268	0.31	0.74	48

*Includes all reactors that reported, although all of them may not have been in commercial operation for a full year.

facilities, the total number of individuals monitored by the four categories increased to a six-year high of 105,894, as did the number receiving a measurable exposure which increased to 61,916. The total collective dose, however, decreased slightly from last year's value which resulted in a decrease in the average individual dose.

Since personnel monitoring data has frequently been found to have log-normal distributions,[4] trends in data reported by these four categories of licensees during the years 1973 through 1978 might be more easily observed from log-probability plots of the data. If the data are log-normally distributed, the data points should form a straight line when plotted on log-probability paper on which cumulative probabilities are laid off on the vertical axis at distances proportional to the corresponding number of standard deviations above or below the median, and the dose is plotted on the horizontal axis which has a logarithmic scale. Distributions in which there are annual doses that exceed 2 rems frequently depart from a straight line because of the licensees' efforts to meet various recommendations and limits.

Figure 1 displays log-probability plots of the data reported by four categories (summed to form a single group) of NRC licensees for each of the years 1974 through 1978. One can see that with the exception of the higher percentage of doses less than 2 rems in 1974, and the smaller percentage of doses greater than 4 rems in 1978, (shown by a shift upward of the curves) the distribution of doses changed very little. Also, shown in Figure 1 is a

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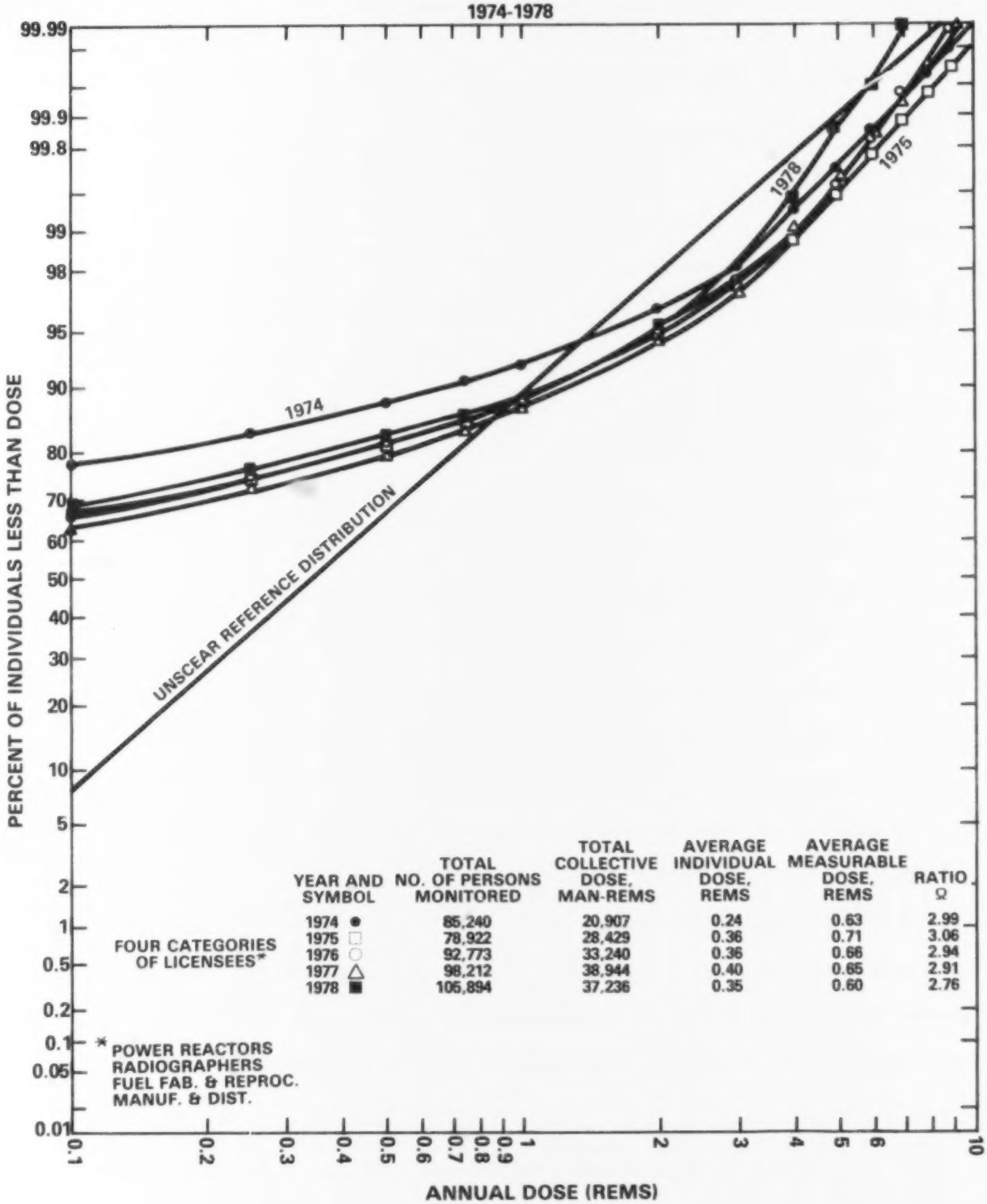
[4] United Nations, "Report of the Scientific Committee on the Effects of Atomic Radiation 1977," General Assembly of Official Records, Thirty-Second Session, Supplement No. 40, United Nations, New York.

Figure 1

Annual Dose Distributions for Four Categories of Licensees 1974-1978



YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	RATIO Ω
1974 ●	85,240	20,907	0.24	0.63	2.99
1975 □	78,922	28,429	0.36	0.71	3.06
1976 ○	92,773	33,240	0.36	0.66	2.94
1977 △	98,212	38,944	0.40	0.65	2.91
1978 ■	105,894	37,236	0.35	0.60	2.76

FOUR CATEGORIES OF LICENSEES*

* POWER REACTORS
RADIOGRAPHERS
FUEL FAB. & REPROC.
MANUF. & DIST.

plot of the Reference Distribution developed by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).[5] It was defined to have properties* "that would comply with the intent of the International Commission on Radiological Protection (ICRP) dose limitation system for occupationally exposed persons and would be convenient for uniform comparison with other exposure distributions." One parameter that UNSCEAR selected was a dimensionless quantity, Ω, defined to be the ratio of the fraction of the collective dose due to annual doses above 1.5 rems found in the observed distribution to the fraction found in the Reference Distribution. For the Reference Distribution, this fraction ($S_{>1.5}/S$) can be shown to be 0.202, and in the observed distribution it can be calculated by dividing the collective dose due to annual doses greater than 1.5 rems ($S_{>1.5}$) by the total collective dose (S). Therefore, for any observed distribution, $\Omega = \frac{1}{0.202} (S_{>1.5}/S) = 4.95 (S_{>1.5}/S)$.[6] Calculation of this ratio allows one to quickly compare the contribution to the collective dose made by the higher doses existing in observed distributions.

Figure 1 shows the value of Ω for each of the years 1974 through 1978, and one can see that Ω was smallest in 1978, reflecting the shift upward in

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[5] Ibid, Footnote 4, page 49.

*The properties are that (1) the distribution of annual doses is log-normal, (2) the mean of the annual dose distribution is 0.5 rem, and (3) the percentage of individuals having doses exceeding an annual dose of 5 rems is one-tenth of one percent (0.1%).

[6] W. Kraus, "Proposed Changes in the Statistical Evaluation of Occupational Doses," Health Physics, Vol. 38, No. 3.

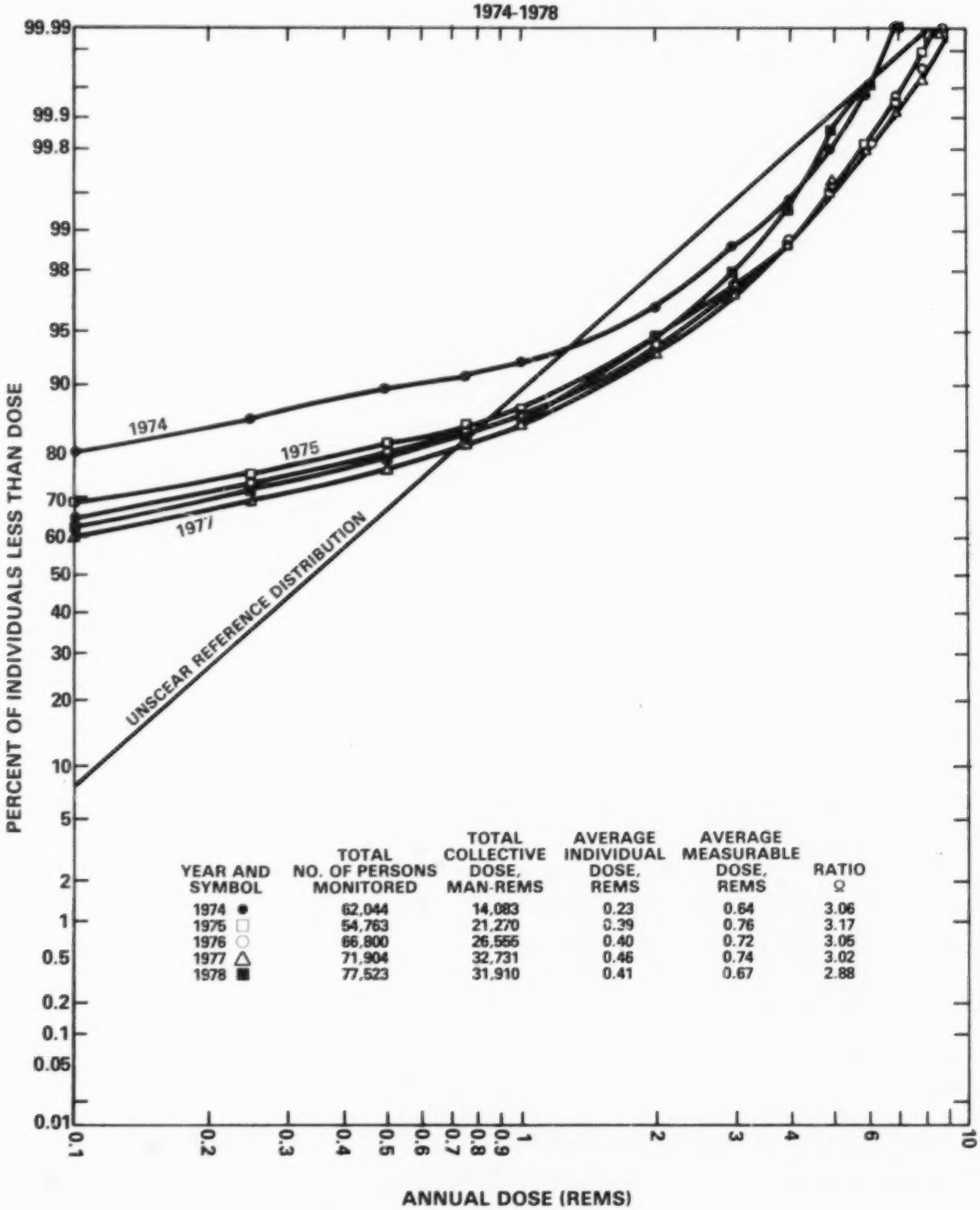
the plot of the higher doses. All of the values of Ω are greater than 1.00, which indicates that the licensees are incurring doses exceeding 1.5 rems to a greater extent than that of the Reference Distribution. It should also be noted that a change in the value of Ω does not imply a comparable change in the average individual dose or in the total collective dose. All of these parameters should be examined in order to study trends in occupational exposure, and they will all be shown at the bottom of each log-probability plot.

2. Annual Dose Distributions for Commercial Power Reactors

Figure 2 presents log-probability plots of the annual dose distribution reported by nuclear power facilities for each of the years 1974 through 1978. Since the number of individuals monitored by these facilities comprise some 70% of the total number of monitored individuals reported by the four categories of licensees shown in Figure 1, the curves look very similar to those in that figure. The average individual doses are slightly higher, as are the values of Ω, indicating that a larger percentage of the cumulative dose incurred by power reactor workers was due to doses exceeding 1.5 rems than was that of the group of four categories of licensees. The values of Ω range from 3.17 in 1975 to 2.88 in 1978, exhibiting a trend toward smaller values of Ω which reflects a decrease in the proportion of individuals receiving higher doses, especially in those exceeding 4 rems. This may be the result of increased regulatory efforts to ensure that personnel exposures are kept "as low as reasonably achievable" (ALARA). However, the increasing number of individuals monitored by nuclear power facilities results in this category of NRC licensees having the largest collective dose, as can be seen in Table 8.

Figure 2

Annual Dose Distributions of Commercial Power Reactors 1974-1978



YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	RATIO Ω
1974 ●	62,044	14,083	0.23	0.64	3.06
1975 □	54,763	21,270	0.39	0.76	3.17
1976 ○	66,800	26,555	0.40	0.72	3.05
1977 △	71,904	32,731	0.46	0.74	3.02
1978 ■	77,523	31,910	0.41	0.67	2.88

TABLE 8

LICENSE PROGRAM CODE IN DESCENDING ORDER OF EXTRAPOLATED COLLECTIVE DOSE

1978

LICENSE CATEGORY and (Program Code)		Extrapolated Collective Dose, Man-rems	Average Collective Dose Per License, Man-rems
Light Water Power Reactors	(41111)	31,910	462
Institutional-Other	(02120)	6,280	4
Radiography-Multiple Loc.	(03320)	2,950	13
Well Logging	(03211)	1,740	22
Institutional-Broad	(03110)	1,640	17
*Marketing-Broad	(02110)	1,560	43
Manuf. & Dist.-Broad	(03211)	751	54
Other Measuring Systems	(03120)	650	<1
UF_6 Convrsn. Fuel Fab. & Scrap Recovery	(21210)	602	120
Plutonium Fuel Fabrication	(21120)	580	194
Academic-Broad	(01100)	560	16
Uranium Fuel Fabrication	(21230)	520	65
Private Practice	(02200)	460	1
Academic-Other	(03212)	360	1
Radiography-Single Loc.	(02300)	330	2
*Marketing-Other	(03310)	310	2
Teletherapy	(01200)	300	1
Res. & Dev. - Broad	(03610)	266	3
Other Uranium>150 kg.	(11300)	240	1
Research Reactors	(42150)	220	3
Uranium Mills	(11100)	180	11
Res. & Dev. -Other	(03620)	160	<1
Plutonium-Other Uses	(21130)	150	25
UF_6 Production Plants	(11400)	131	66
Civil Defense	(03710)	110	1
Irradiator, >10,000 Ci	(03520)	105	2
Waste Disposal-Other	(03232)	100	7
Manuf. & Dist.-Other	(03212)	100	8
Uranium-Other Uses	(21240)	70	14
Fuel Storage	(23100)	70	17
Neutron Sources	(22120)	60	<1
Plutonium Fuel Fab. & Scrap Recovery	(21110)	41	14
Other Medical	(02400)	40	1
Medical Distribution	(02500)	40	1
Irradiator, <10,000 Ci	(03510)	40	<1
Fuel Reprocessing	(43110)	23	23
Unencapsulated SNM	(22110)	20	2
Instit. Cardiac Pacemaker	(22160)	20	<1
Uranium Fuel Fab. & Scrap Recovery	(21220)	20	4
Other SNM Sources	(22140)	10	<1
Leak Test	(03220)	10	1
Uranium Sources	(22200)	10	<1
Waste Disposal-Burial	(03231)	3	3
Gas Cooled Power Reactors	(41120)	2	2
Nuclear Laundry	(03218)	0	<1
Other Uranium <150 kg.	(11200)	0	<1
Power Sources	(03400)	0	0
Uranium Solution Mines	(11500)	0	0
Power Sources	(22130)	0	0
SNM Storage, Only	(23200)	0	0
Critical Exper. Facilities	(42160)	0	0
Pacemakers, Instit.	(02600)	No Data	No Data
Test Reactors	(42140)	No Data	No Data

*Excluding the subset "Manufacturing & Distribution."

Table 9 presents a summary of the annual exposure and production data that has been reported by the two types of U.S. commercial nuclear power facilities, PWRs and BWRs, for the years 1973 through 1978. One can see that while the number of reactors and the collective dose did little more than double, the number of individuals receiving measurable doses more than tripled. However, the gross electrical energy generated increased by a factor of four such that the collective dose per megawatt-year of electricity generated fell from a value of 1.9 in 1973 to that of 1.0 in 1978. One can see that the value of this parameter has been greater for BWRs than PWRs for the last five years, as has the number of workers monitored per reactor, the collective dose per reactor, and the average measurable dose per worker. Figure 3 graphically displays annual data reported by BWRs and PWRs. A more detailed presentation and analysis of the annual exposure information reported by nuclear power reactors can be found in NUREG-0594, "Occupational Radiation Exposure at Commercial Nuclear Power Reactors, 1978."

3. Annual Dose Distributions for Industrial Radiographers

Figure 4 presents log-probability plots of the annual dose distributions reported by NRC-licensed industrial radiography firms for each of the years 1974 through 1978. Again, there is a shift upward of the plots of the data for the years 1976, 1977, and 1978, indicating fewer doses in the higher ranges. Correspondingly, the value of Ω decreased from a high of 2.62 in 1975 to a low of 2.13 in 1978, and the average measurable dose per person decreased from 0.60 rems to 0.44 rems.

Figure 5 presents log-probability plots of the annual dose distributions reported by the two types of radiography licensees: those licensed to perform

TABLE 9*

SUMMARY OF ANNUAL EXPOSURES REPORTED BY NUCLEAR POWER FACILITIES 1973-1978

Year	Reactor Type	Number of Reactors Included	Total Number of Man-Rems	No. of Workers With Measurable Doses	Total Megawatt-Yrs. Generated	Average Annual Dose (Rems/Worker)	Average No. of Man-Rems Per Reactor	Average No. of Workers Per Reactor	Man-Rems Per Megawatt-Yr.
1973	PWR	12	9,399	9,440	3,770	1.00	783	787	2.5
	BWR	12	4,564	5,340	3,394	0.85	380	445	1.3
	Total	24	13,963	14,780	7,164	0.94	582	616	1.9
1974	PWR	20	6,627	9,697	6,824	0.68	331	485	1.0
	BWR	14	7,095	8,769	4,059	0.81	507	626	1.7
	Total	34	13,722	18,466	10,883	0.74	404	543	1.3
1975	PWR	26	8,268	10,884	11,983	0.76	318	419	0.7
	BWR	18	12,611	14,607	5,786	0.86	701	812	2.2
	Total	44	20,879	25,491	17,769	0.82	475	579	1.2
1976	PWR	30	13,807	17,588	13,325	0.79	460	586	1.0
	BWR	23	12,626	17,859	8,586	0.71	549	776	1.5
	Total	53	26,433	35,447	21,911	0.75	499	669	1.2
1977	PWR	34	13,469	20,878	17,346	0.65	396	614	0.8
	BWR	23	19,042	21,388	9,098	0.89	828	930	2.1
	Total	57	32,511	42,266	26,444	0.77	570	742	1.2
1978	PWR	39	16,713	25,720	19,840	0.65	429	659	0.8
	BWR	25	15,096	20,278	11,774	0.74	604	811	1.3
	Total	64	31,809	45,998	31,614	0.69	497	719	1.0

*The figures on this table are based on the number of nuclear power reactors that had been in commercial operation for at least one year as of December 31 of each of the years indicated.

FIGURE 3

PLOTS OF AVERAGE ANNUAL VALUES AT BOILING AND PRESSURIZED WATER REACTORS

1969 - 1978

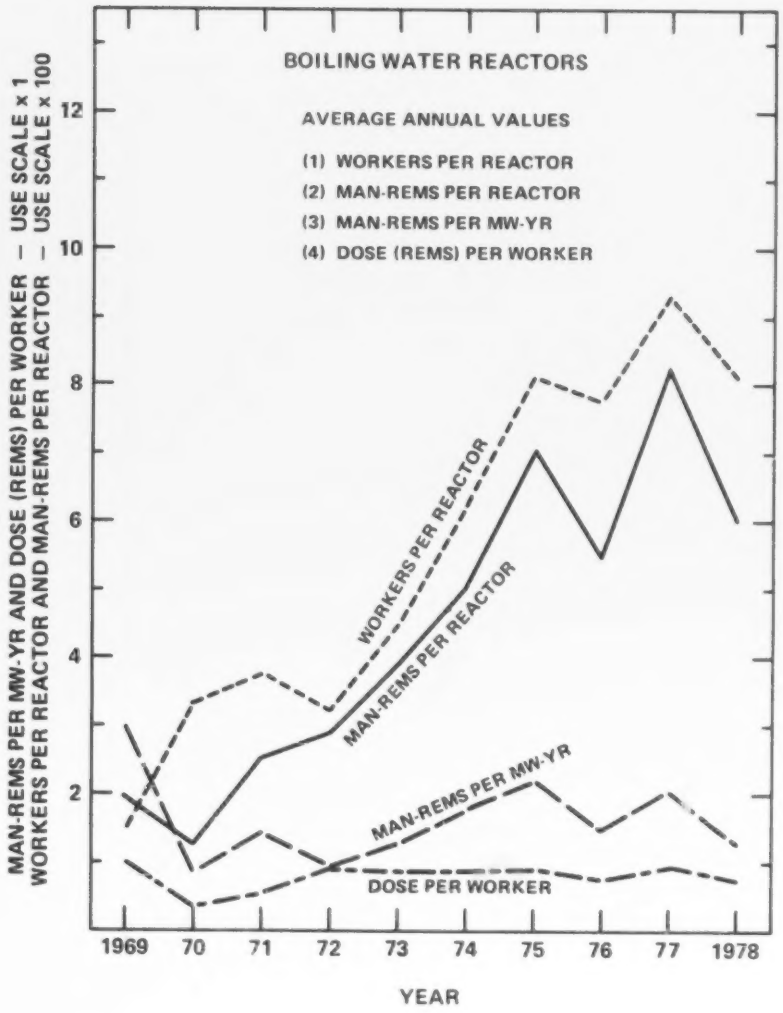
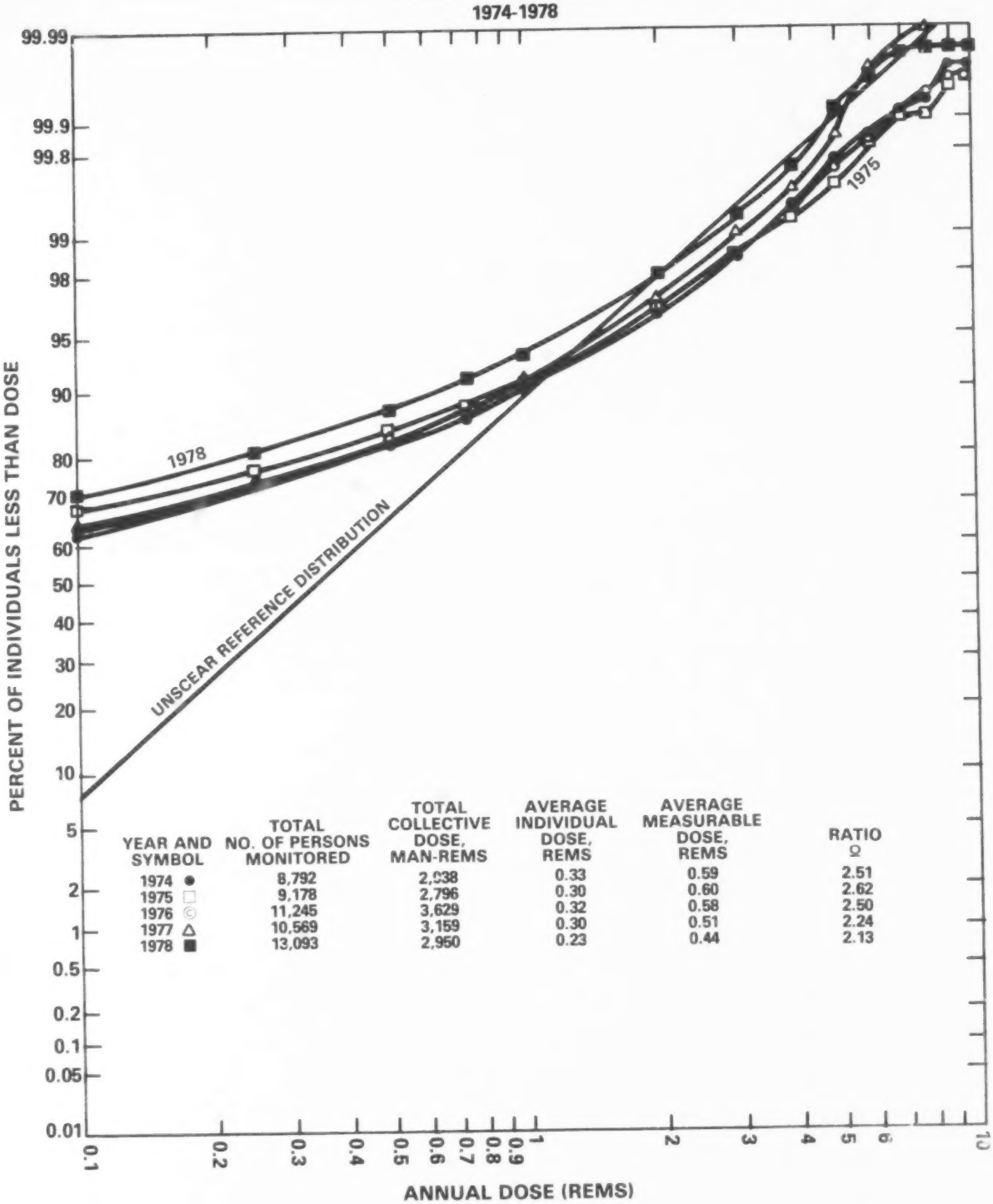


Figure 4

Annual Dose Distributions of Industrial Radiographers

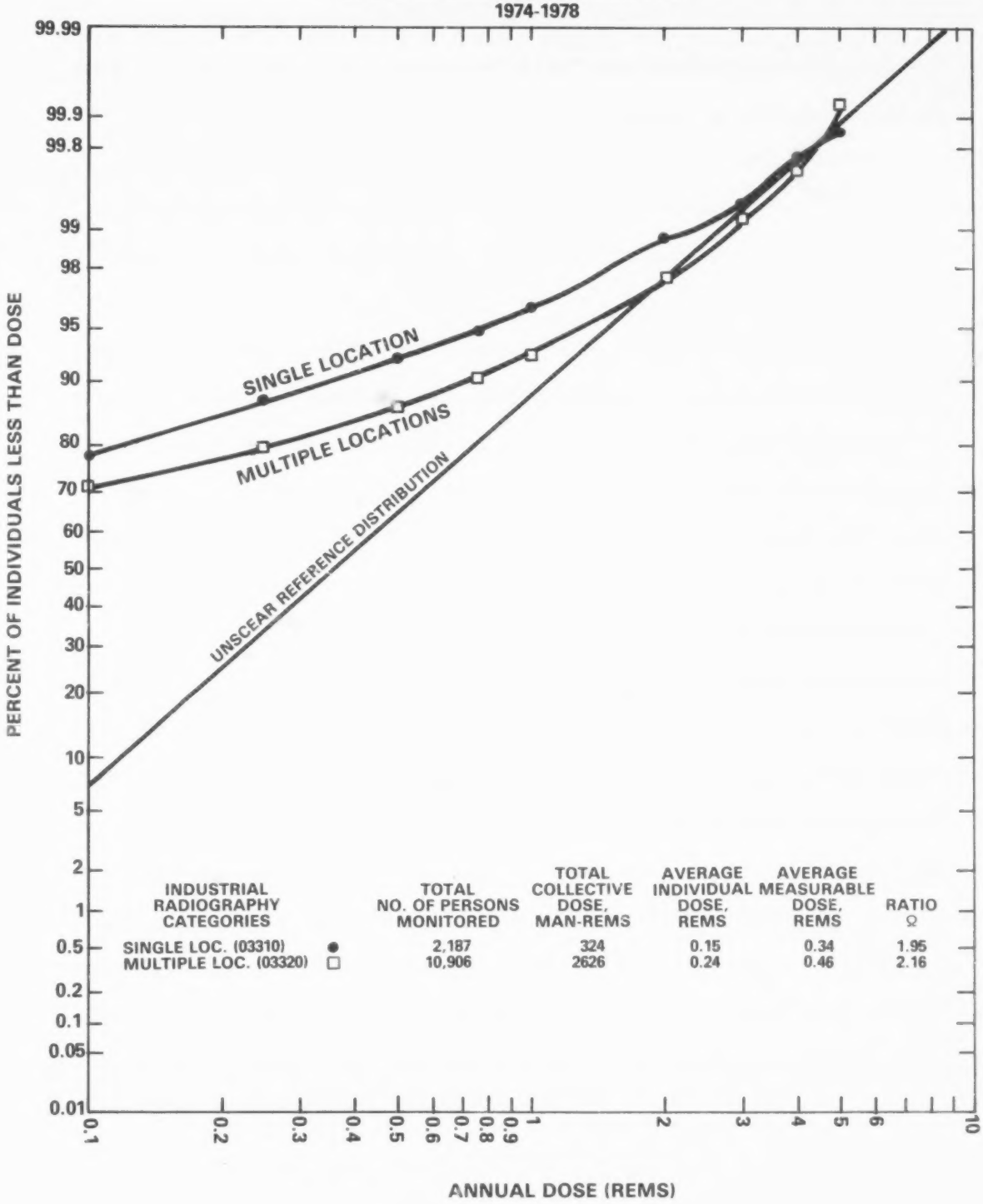
1974-1978



YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	RATIO Ω
1974 ●	8,792	2,938	0.33	0.59	2.51
1975 □	9,178	2,796	0.30	0.60	2.62
1976 ◎	11,245	3,629	0.32	0.58	2.50
1977 △	10,569	3,159	0.30	0.51	2.24
1978 ■	13,093	2,950	0.23	0.44	2.13

Figure 5

Annual Dose Distributions of Two Types of Industrial Radiography Licensees 1974-1978



INDUSTRIAL RADIOGRAPHY CATEGORIES		TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	RATIO ♀
SINGLE LOC. (03310)	●	2,187	324	0.15	0.34	1.95
MULTIPLE LOC. (03320)	□	10,906	2626	0.24	0.46	2.16

radiography at a single location, in plant; and those licensed to perform radiography at multiple locations, in the field. One can see that a higher percentage of the individuals monitored by the first type received lower doses than those monitored by the second. This is reflected in the lower values of the average doses and of Ω for the single location licensees. Also fewer overexposures to radiography personnel are reported by firms licensed for in plant radiography.

The average doses calculated from this annual exposure data is inversely proportional to the number of individuals reported as being monitored. Therefore, if licensees elect to monitor individuals other than those directly associated with radiographic activities and the handling of the radioactive material, the number of individuals reported will be greater than the number of persons actually conducting radiography, and the average dose will be less than that likely to be incurred by a full-time radiographer.[7] In an attempt to determine the magnitude of this problem, a report "An Economic Study of the Radionuclides Industry"[8] was examined. Based on a survey of certain NRC and Agreement State licensees, this report estimated that there were a total of 4,500 monitored individuals directly associated with the production of radiographs using radioactive material in the U.S. during 1978, and those individuals contributed 3,400 person-years of work in this field. Since half of the States are Agreement States and would have licensed the material rather

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[7]Personal communication with S. McGuire, Office of Standards Development, U.S. Nuclear Regulatory Commission.

[8]Ibid, Footnote 2, page 7.

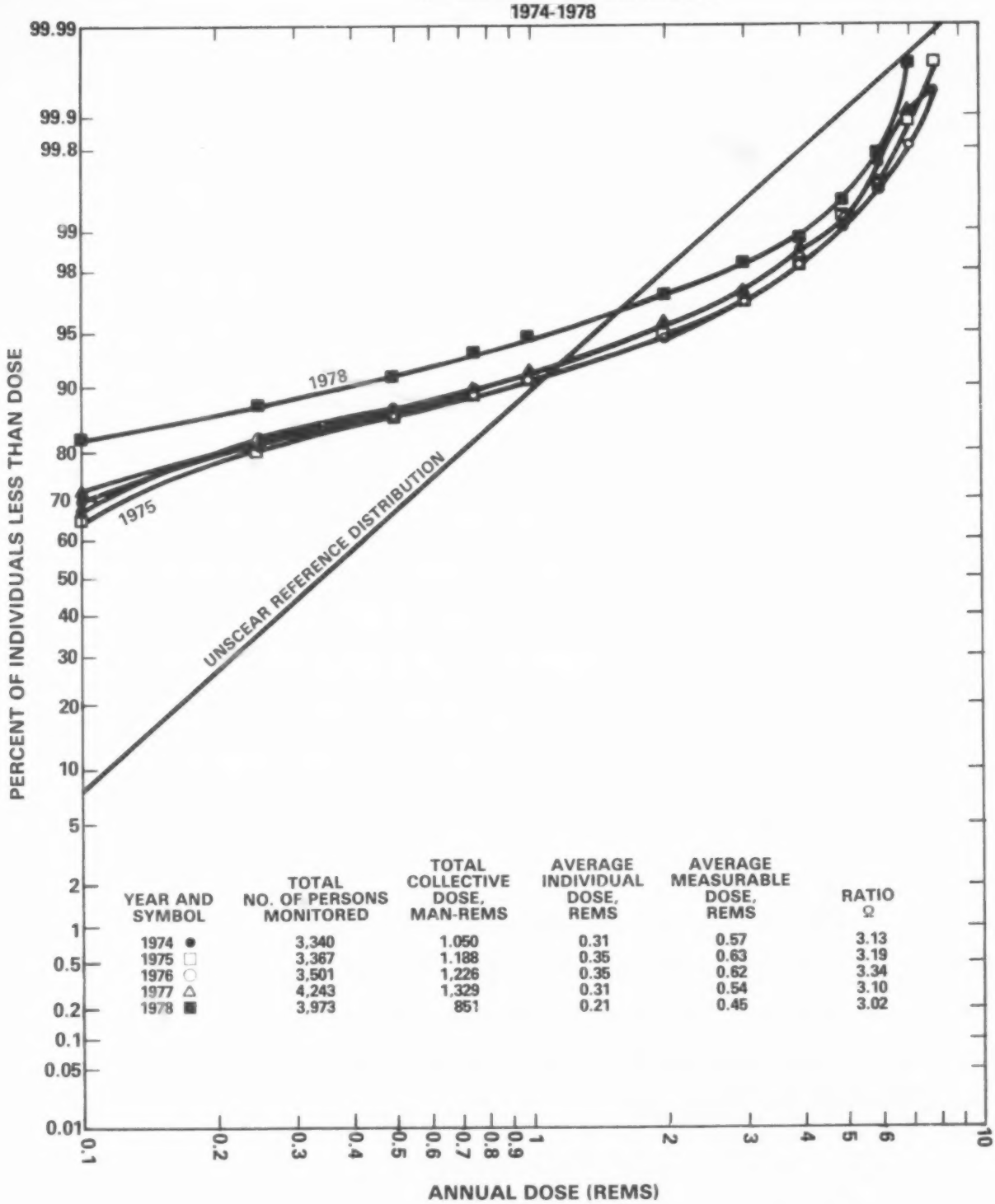
than the NRC, these figures have been divided in half to obtain a rough estimate of the number of radiographers using NRC-licensed material. Dividing the collective dose, 2,950 man-rems calculated from the NRC licensees' annual reports, by this estimated number of radiographers (2,350), one obtains an average dose per radiographer of 1.3 rems. The number of person-years of work contributed by these radiographers could similarly be estimated to be 1,700 person-years, and the division of the collective dose by this number would yield 1.7 rems as the average dose that would have been received by a radiographer working full-time during 1978. These averages are 3 and 4 times that of the average measurable dose (0.44 rem), developed from the information reported by the NRC licensees. One should realize that NRC licensees may monitor and report everyone remotely associated with the licensed material, such as secretaries, security personnel, visitors, repairmen, janitors, etc., that may have been exposed for a few minutes or a year. It should not be assumed that the average developed from this data is for a homogeneous population directly involved in one particular activity for the entire year.

4. Annual Dose Distributions for Manufacturers and Distributors

Figure 6 presents log-probability plots of the annual dose distributions reported by Manufacturers and Distributors, a subset of NRC's Marketing licensees. One can see a definite decrease in the collective dose in 1978 when it fell to a low of 851 man-rems, and the average measurable dose declined to 0.45 rem. The value of Ω also fell to a low of 3.02 in 1978, but it is still larger than that of the other three categories in this group of four, as it has been since 1973.

Figure 6

Annual Dose Distributions of Manufacturers and Distributors 1974-1978



YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	RATIO Ω
1974 ●	3,340	1,050	0.31	0.57	3.13
1975 □	3,367	1,188	0.35	0.63	3.19
1976 ○	3,501	1,226	0.35	0.62	3.34
1977 △	4,243	1,329	0.31	0.54	3.10
1978 ■	3,973	851	0.21	0.45	3.02

As is the case with the Marketing category, this subset is comprised of two types of Manufacturing and Distribution licensees - those issued Broad licenses and those issued Other licenses. The dose distributions reported by these two types, 14 of the Broad licenses and 13 of the Other licenses, are plotted in Figure 7. One can see that there are significant differences in the parameters for these two types. One reason might be that the Broad licenses allow the possession of much larger quantities of materials. The value of Ω was found to be 3.18 for those having Broad licenses; such a large value of Ω indicates that an unusually high percentage of the collective dose was incurred by workers whose annual doses exceeded 1.5 rems. As shown in Table 10, this group was also one of seven types of NRC licensees having an average measurable dose in excess of 0.50 rem. Perhaps the licensees should expend greater efforts in ensuring that doses are maintained as low as is reasonably achievable (ALARA).

5. Annual Dose Distributions for Fuel Fabricators and Reprocessors

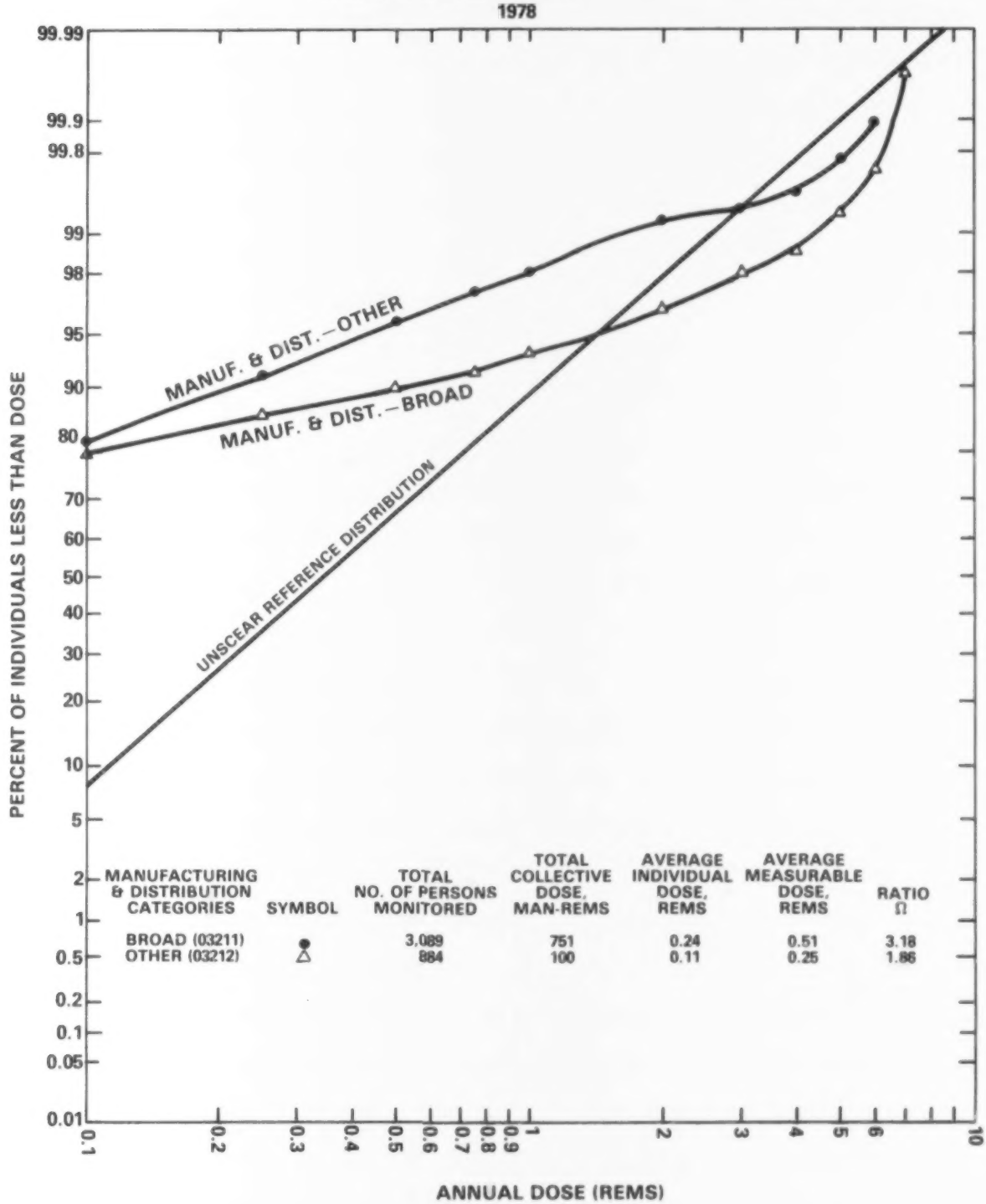
Figure 8 presents log-probability plots of the annual dose distributions reported by fuel fabricators and reprocessors for each of the years 1974 through 1978. The curves tend to shift upward each year and the average measurable dose steadily declined from 0.60 rem to 0.25 rem, as does the ratio Ω which fell from 3.02 to 1.20.

Figure 9 presents log-probability plots of the 1978 annual dose distributions reported by the six types of licensees that are usually lumped together to form this group. One can see that a higher percentage of the workers engaged in plutonium fuel fabrication activities received annual doses in excess of 1.5 rems than did those employed in the other five activities,

Figure 7

Annual Dose Distributions of Two Types of Manuf. & Dist. Licensees

1978



MANUFACTURING & DISTRIBUTION CATEGORIES	SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	RATIO Ω
BROAD (03211)	●	3,089	751	0.24	0.51	3.18
OTHER (03212)	△	884	100	0.11	0.25	1.86

TABLE 10
LICENSE PROGRAM CODE IN DESCENDING ORDER OF
AVERAGE MEASUREABLE DOSE
1978

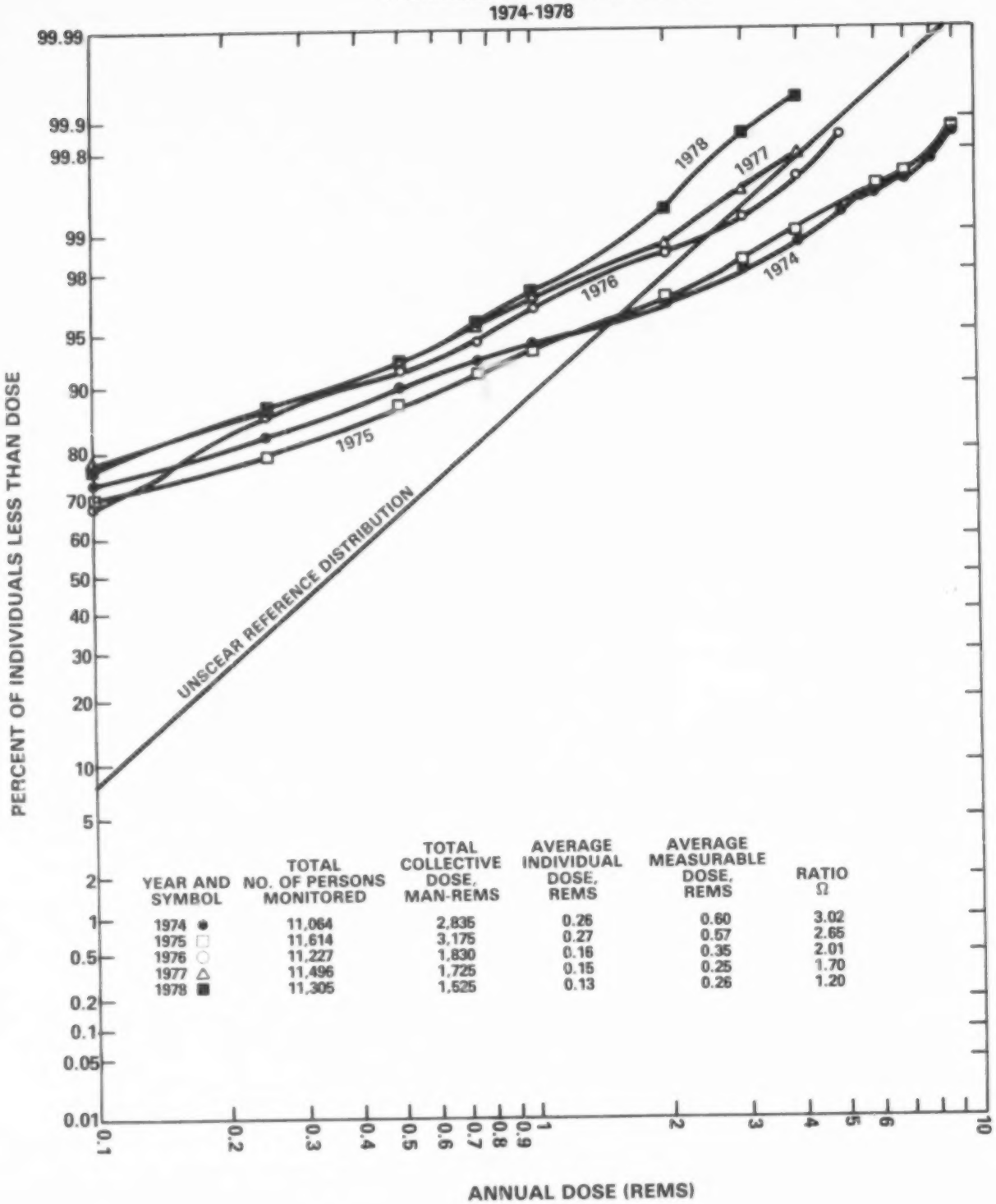
LICENSE CATEGORY and (Program Code)		AVERAGE MEASURABLE DOSE, REMS	AVERAGE INDIVIDUAL DOSE, REMS	RATIO** Ω
Unencapsulated SNM	(22110)	0.99	0.13	2.89
Fuel Storage	(23100)	0.94	0.43	1.77
Light Water Power Reactors	(41111)	0.67	0.41	2.88
Waste Disposal-Other	(03231)	0.57	0.28	3.54
Plutonium Fuel Fab.	(21120)	0.56	0.32	2.71
Instit. Cardiac Pacemaker	(22160)	0.56	0.27	2.93
Manuf. & Distrib.-Broad	(03211)	0.51	0.24	3.18
Radiography-Multiple Loc.	(03320)	0.46	0.24	2.16
*Marketing-Broad	(03211)	0.36	0.24	1.07
Well Logging	(03110)	0.36	0.27	1.72
Radiography-Single Loc.	(03310)	0.34	0.15	1.95
Fuel Reprocessing	(43110)	0.32	0.19	0.48
Private Practice	(02200)	0.28	0.20	1.42
Manuf. & Distrib.-Other	(03212)	0.25	0.11	1.86
Institutional-Other	(02120)	0.25	0.17	1.27
Leak Test	(03220)	0.25	0.09	1.03
Other Uranium>150 kg.	(11300)	0.24	0.10	0.79
UF_6 Convrsn, Fuel Fab & Scrap Recovery	(21210)	0.24	0.13	0.52
UF_6 Production Plants	(11400)	0.23	0.21	0.40
Uranium Mills	(11100)	0.22	0.18	0.41
Nuclear Laundry	(03218)	0.22	0.07	0.00
Uranium Sources	(22200)	0.22	0.02	2.85
Medical Distribution	(02500)	0.21	0.15	0.00
Uranium-Other Uses	(21240)	0.20	0.15	1.66
Other SNM Sources	(22140)	0.20	0.03	0.93
Waste Disposal-Burial	(03231)	0.20	0.17	0.00
Research Reactors	(42150)	0.19	0.06	2.18
Uranium Fuel Fab.	(21230)	0.18	0.10	0.97
*Marketing-Other	(03212)	0.17	0.05	2.06
Teletherapy	(02300)	0.18	0.11	0.72
Irradiator, >10,000 Ci	(03520)	0.16	0.05	0.70
Institutional-Broad	(02110)	0.15	0.07	0.74
Academic-Broad	(01100)	0.13	0.06	0.64
Plutonium Fuel Fab. & Scrap Recovery	(21110)	0.13	0.06	0.45
Academic-Other	(01200)	0.12	0.03	0.62
Res. & Dev.-Broad	(03610)	0.11	0.02	1.19
Neutron Sources	(22120)	0.11	0.02	0.89
Irradiator, <10,000 Ci	(03510)	0.11	0.02	0.73
Plutonium-Other Uses	(21130)	0.10	0.04	0.07
Other Measuring Systems	(03120)	0.10	0.03	0.66
Uranium Fuel Fab. & Scrap Recovery	(21220)	0.09	0.05	0.00
Other Medical	(02400)	0.09	0.03	0.53
Res. & Dev.-Other	(03620)	0.07	0.02	0.06
Civil Defense	(03710)	0.06	0.04	0.05
Other Uranium <150 kg.	(11200)	0.06	0.03	0.00
Gas Cooled Power Reactors	(41120)	0.05	0.00	0.00
SNM Storage, Only	(23200)	0.05	0.00	0.00
Power Sources (Byproduct)	(03400)	No monitoring required		
Uranium Solution Mines	(11500)	"		
Power Sources (SNM)	(22130)	"		
Critical Exper. Facilities	(42160)	"		
Pacemakers, Instit	(02600)	No data for this program code		
Test Reactors	(42140)	No data for this program code		

*Excluding the subset "Manufacturing & Distribution".

**The ratio of the fraction of the collective dose due to annual doses greater than 1.5 rems in the observed distribution to fraction of the UNSCEAR reference distribution. (See Section

Figure 8

Annual Dose Distributions of Fuel Fabricators and Reprocessors 1974-1978

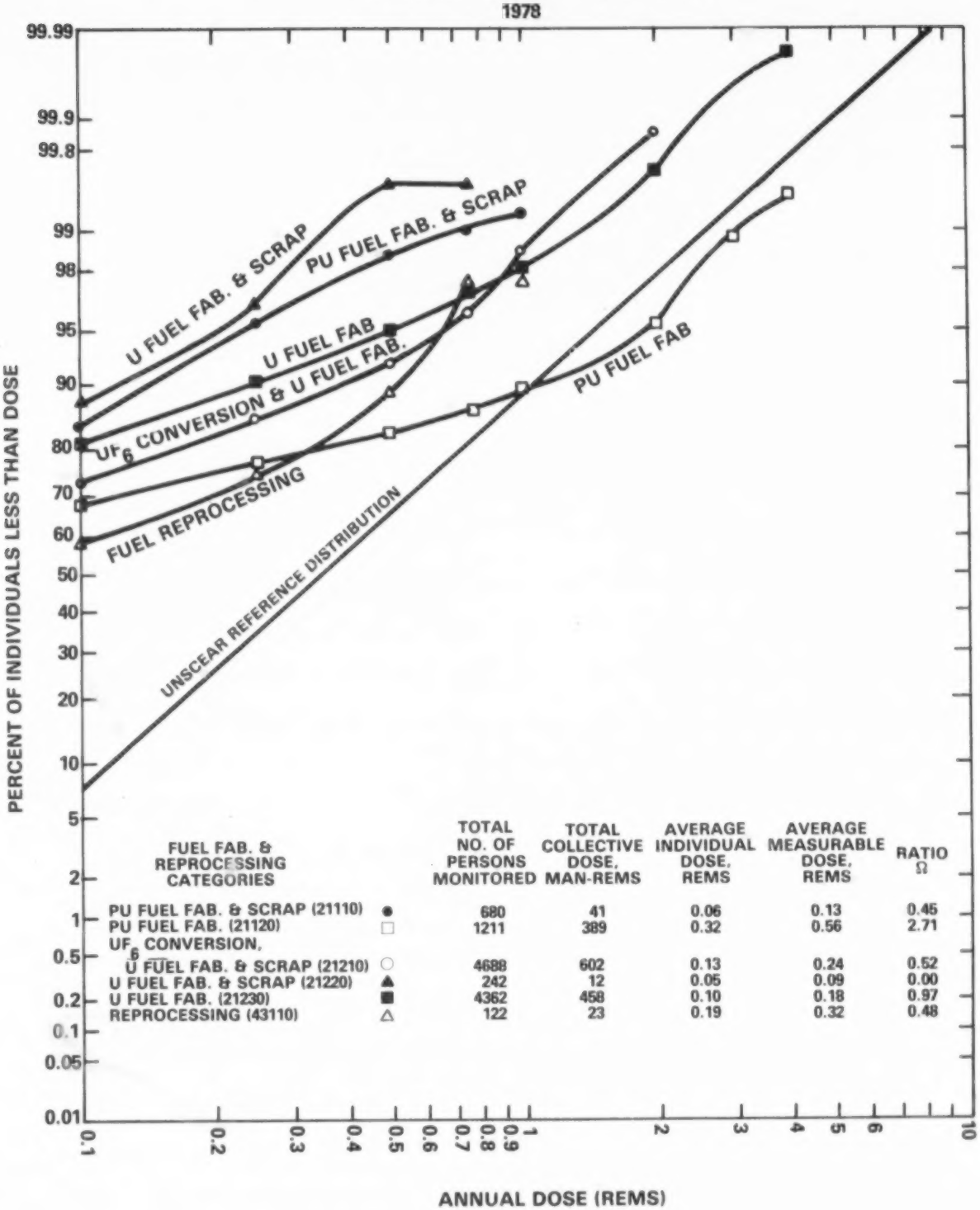


YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	RATIO Ω
1974 ●	11,064	2,835	0.26	0.60	3.02
1975 □	11,614	3,175	0.27	0.57	2.65
1976 ○	11,227	1,830	0.16	0.35	2.01
1977 △	11,496	1,725	0.15	0.25	1.70
1978 ■	11,305	1,525	0.13	0.26	1.20

Figure 9

Annual Dose Distributions of Types of Fuel Fab. & Reprocessing Licensees

1978



FUEL FAB. & REPROCESSING CATEGORIES		TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	RATIO Ω
PU FUEL FAB. & SCRAP (21110)	●	680	41	0.06	0.13	0.45
PU FUEL FAB. (21120)	□	1211	389	0.32	0.56	2.71
UF_6 CONVERSION, U FUEL FAB. & SCRAP (21210)	○	4688	602	0.13	0.24	0.52
U FUEL FAB. & SCRAP (21220)	▲	242	12	0.05	0.09	0.00
U FUEL FAB. (21230)	■	4362	458	0.10	0.18	0.97
REPROCESSING (43110)	△	122	23	0.19	0.32	0.48

and they had the highest average dose. Licensees engaged in uranium hexafluoride (UF_6) conversion, uranium fuel fabrication and scrap recovery reported monitoring the largest number of individuals and the largest collective dose. However, the doses were distributed such that the value of Ω was only 0.52 and the average measurable dose was 0.24 rem.

B. Annual Exposure Data for the Remaining Categories of Licensees

1. Annual Dose Distributions for Medical Licensees

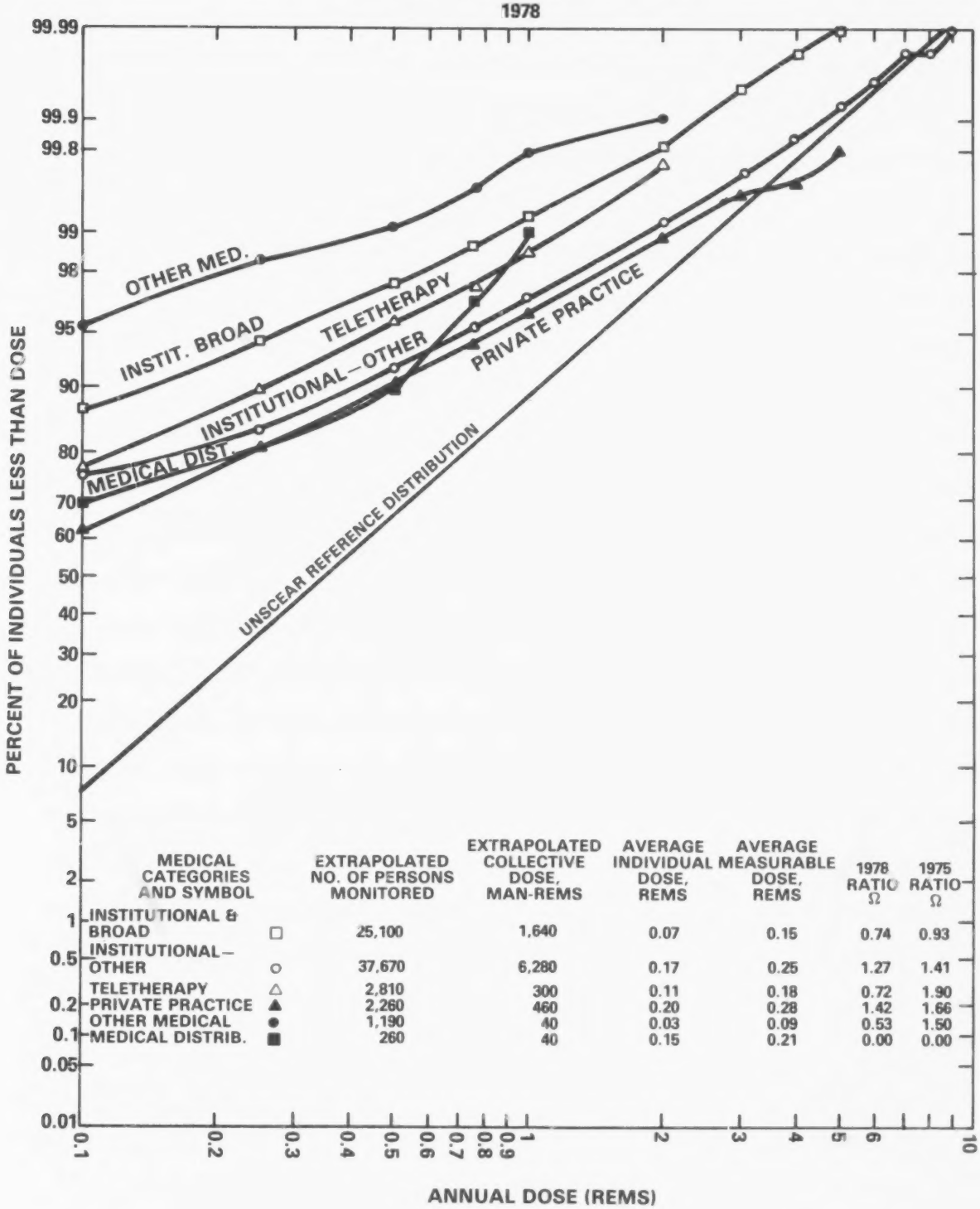
Figure 10 presents log-probability plots of the dose distributions reported by six categories of medical licensees. One can see that the two lowest curves, those for Private Practice and Institutional-Other, have larger values of Ω than the other four curves. Also, it appears that employees of Private Practice licensees have the highest average doses; the number of individuals involved, however, is rather small so that the contribution to the total collective dose is not large. The major portion of the collective dose was reported by the Institutional licensees where a large number of workers received relatively small doses.

As can be seen from Table 3 (page 13), the total occupational collective dose (8,820 man-rems) incurred by workers associated with medical activities involving radioisotopes is second only to that (77,523 man-rems) incurred by workers at nuclear power facilities. It exceeds the sum of the collective doses reported by the other three categories of licensees (radiographers, manufacturers and distributors, and fuel fabricators and reprocessors) that previously submitted annual reports. The doses incurred by medical workers is of particular interest because the majority of workers is young females. In

Figure 10

Annual Dose Distributions of Types of Medical Licensees

1978



MEDICAL CATEGORIES AND SYMBOL		EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1978 RATIO Ω	1975 RATIO Ω
INSTITUTIONAL & BROAD	□	25,100	1,640	0.07	0.15	0.74	0.93
INSTITUTIONAL—OTHER	○	37,670	6,280	0.17	0.25	1.27	1.41
TELETHERAPY	△	2,810	300	0.11	0.18	0.72	1.90
PRIVATE PRACTICE	▲	2,260	460	0.20	0.28	1.42	1.66
OTHER MEDICAL	●	1,190	40	0.03	0.09	0.53	1.50
MEDICAL DISTRIB.	■	260	40	0.15	0.21	0.00	0.00

fact, preliminary estimates by the U.S. Environmental Protection Agency indicate that 20 to 24 year-old females in the medical field comprise one-fourth of all females in the entire U.S. radiation work force.[9] Since there is a possibility of these females becoming pregnant, the somatic risks to radio-sensitive embryos and fetuses should be considered.

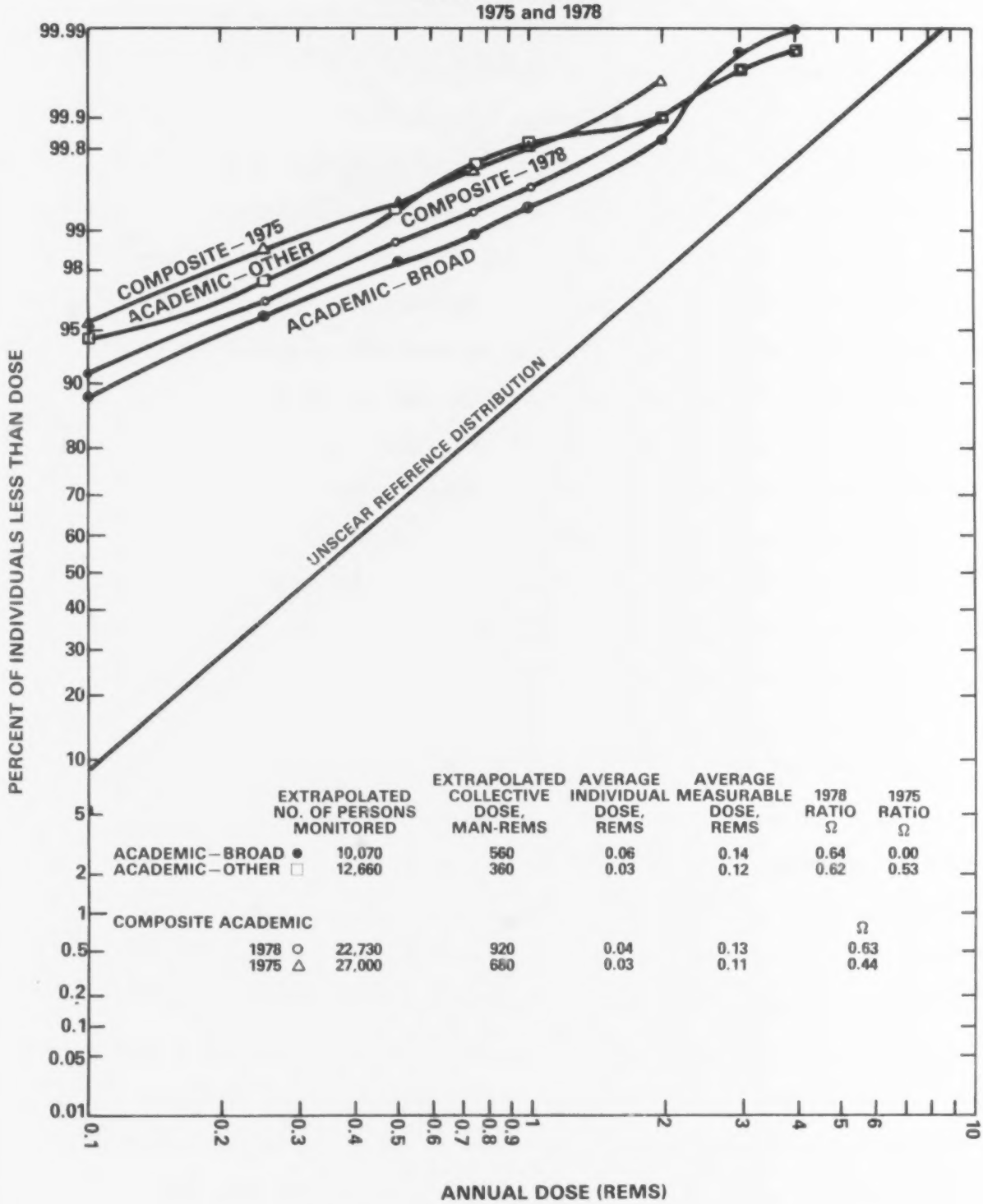
2. Annual Dose Distributions for Academic Licensees

Figure 11 displays four log-probability plots of annual dose distributions: one plot for each of the two types of Academic licensees, Broad and Other, for 1978; one plot for the composite of these two types for 1978; and one for the composite of these two types for 1975. One can see that all of the plots compare favorably with the Reference Distribution, and that the distributions reported by the two types of academic licensees are quite similar with the values of Ω being nearly equal (0.64 for Broad licensees and 0.62 for Other licensees). The value of Ω found for the Institutional and Marketing licensees having "Broad" licenses was also found to be about the same or considerably less than that found for the Other types of these licensees. This implies that the greater potential for exposure associated with the more complex activities of most facilities having a Broad license can be compensated by the larger radiation protection program required by the conditions of such a Broad license. A shift downward in the composite plot for 1978 from that of the plot for 1975 indicates a small increase in the percentage of

[9] Cook, J., Nelson, D., "Occupational Exposures to Ionizing Radiation in the United States: A Comprehensive Summary for 1975," U.S. Environmental Protection Agency, Draft of December 27, 1979.

Figure 11

Annual Dose Distributions of Academic Licensees 1975 and 1978



	EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1978 RATIO Ω	1975 RATIO Ω
ACADEMIC—BROAD ●	10,070	560	0.06	0.14	0.64	0.00
ACADEMIC—OTHER □	12,660	360	0.03	0.12	0.62	0.53
COMPOSITE ACADEMIC					Ω	
1978 ○	22,730	920	0.04	0.13	0.63	
1975 △	27,000	680	0.03	0.11	0.44	

workers receiving higher doses, but the continuing extremely low values of the average doses indicates that the licensees may be monitoring many more people than would be required by the current regulations.

3. Annual Dose Distributions for Research and Development Licensees

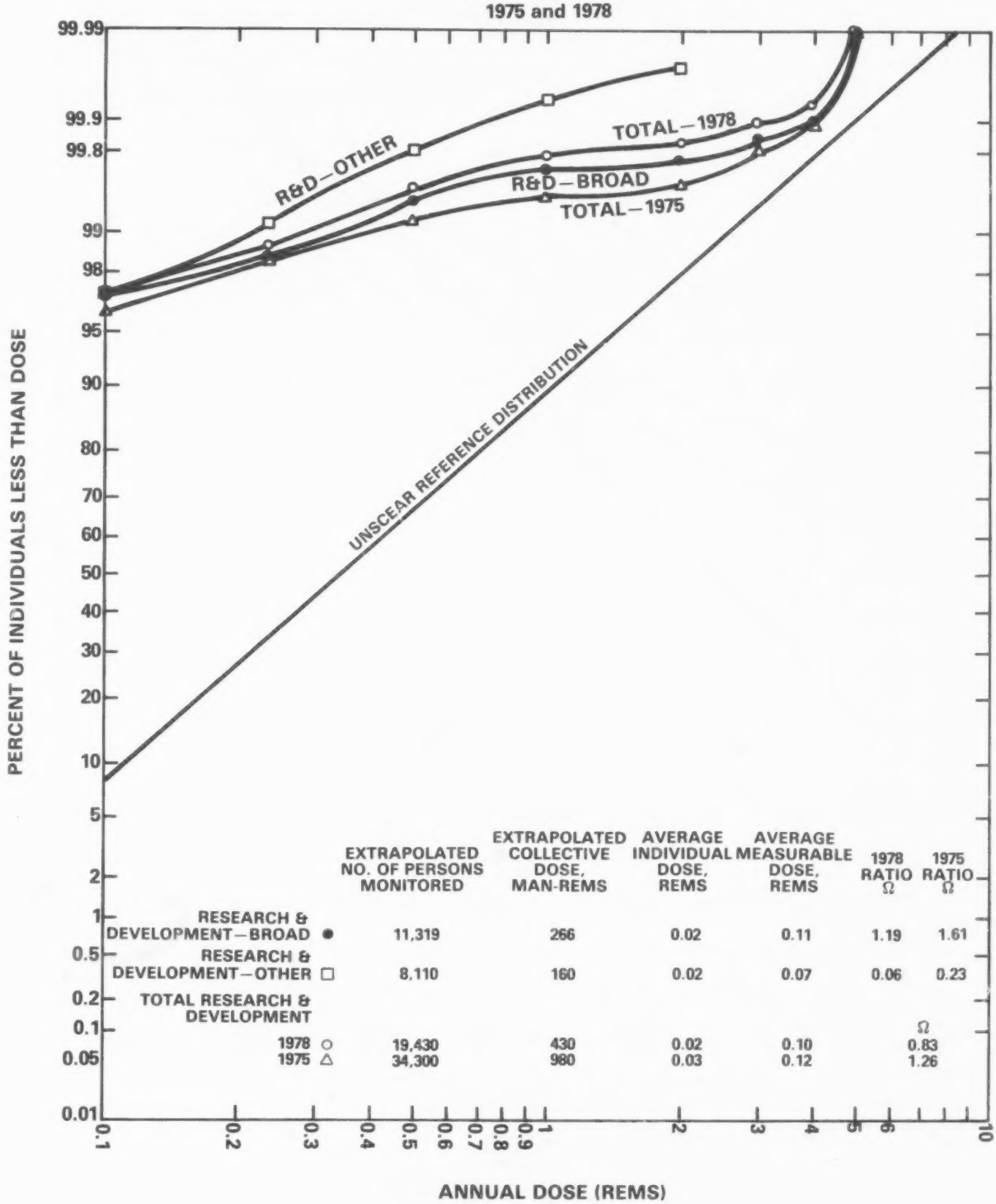
Four plots similar to those shown for Academic licensees are presented in Figure 12. One can see that contrary to that found for the Broad and Other types of Academic licensees, the dose distributions reported by these two types of Research and Development licensees are quite different, particularly in the higher dose ranges, and results in Ω being 1.19 for the Broad licensees and only 0.06 for the Other licensees. Both types reported large numbers of individuals in the very low dose ranges so the average and the collective doses are quite small. Should the dose distribution reported by the Other licensees continue to be such that the value of Ω and the average dose are extremely low, it would imply that all of these workers may not require individual personal monitoring under current regulations.

4. Annual Dose Distributions for Marketing Licensees

The dose distributions reported by Marketing licensees are shown in Figure 13 via four log-probability plots similar to those presented for the two previous categories. One can see that the dose distributions reported by the Marketing licensees compare fairly well with that of the Reference Distribution. However, the Marketing-Other licensees experienced doses exceeding 1.5 rems to a proportionately greater extent, resulting in a value of Ω of 2.06. Although the workers employed by Broad licensees received higher average doses, their administrative and radiation protection procedures were such that the collective dose was more evenly distributed over the

Figure 12

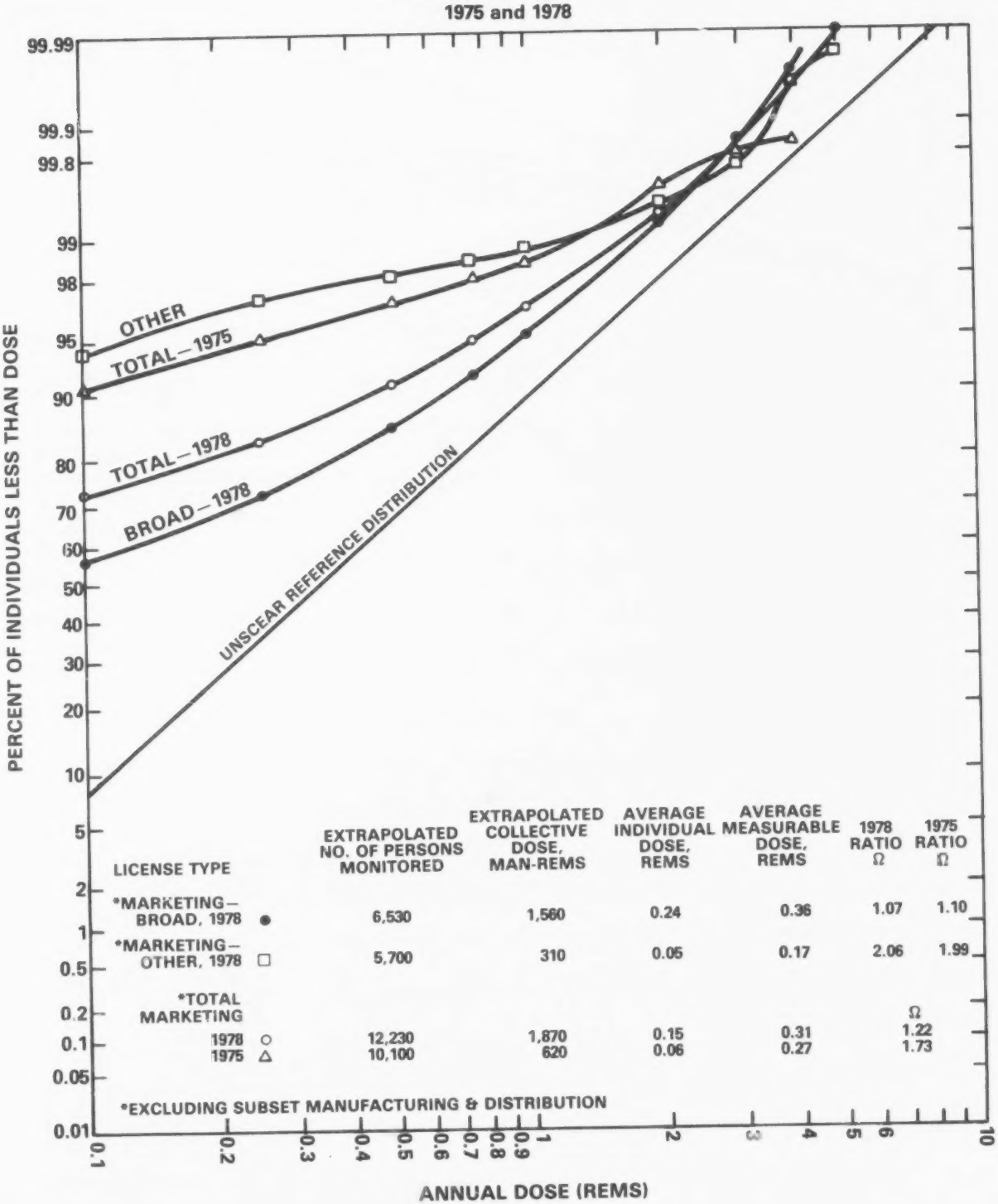
Annual Dose Distributions of
Research & Development Licensees
1975 and 1978



	EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1978 RATIO Ω	1975 RATIO Ω
RESEARCH & DEVELOPMENT—BROAD ●	11,319	266	0.02	0.11	1.19	1.61
RESEARCH & DEVELOPMENT—OTHER □	8,110	160	0.02	0.07	0.06	0.23
TOTAL RESEARCH & DEVELOPMENT						Ω
1978 ○	19,430	430	0.02	0.10		0.83
1975 △	34,300	980	0.03	0.12		1.26

Figure 13

Annual Dose Distributions of
Marketing Licensees
1975 and 1978



LICENSE TYPE	EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1978 RATIO Ω	1975 RATIO Ω
*MARKETING—BROAD, 1978 ●	6,530	1,560	0.24	0.36	1.07	1.10
*MARKETING—OTHER, 1978 □	5,700	310	0.05	0.17	2.06	1.99
*TOTAL MARKETING						Ω
1978 ○	12,230	1,870	0.15	0.31		1.22
1975 △	10,100	620	0.06	0.27		1.73

*EXCLUDING SUBSET MANUFACTURING & DISTRIBUTION

monitored population than was that of the Other licensees. The collective dose incurred by the approximately 6,500 individuals monitored by the Marketing-Broad licensees was 1,560 man-rems, which was about five times that incurred by the 5,700 individuals monitored by the Other licensees. As can be seen from Table 8 (page 54), Marketing-Broad is one of the six categories of licensees in which the collective dose exceeded 1,000 man-rems.

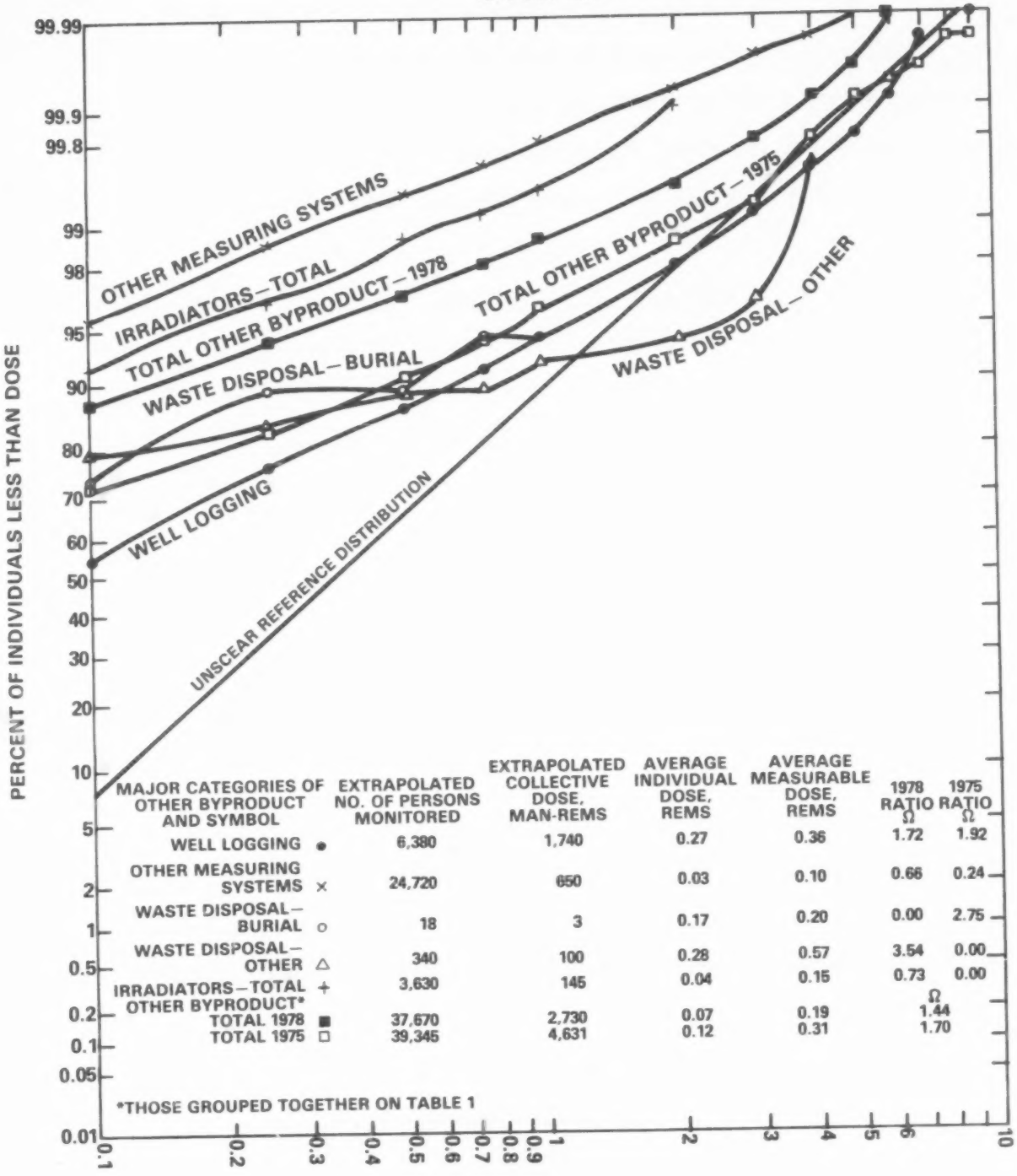
5. Annual Dose Distributions for Other Industrial Byproduct Licensees

Figure 14 presents log-probability plots of the major categories of licensees using byproduct materials for other industrial purposes. One can see that workers monitored by Waste Disposal-Other licensees have the highest average measurable doses of those in this group and, as shown in Table 10 (page 65), it is the fourth highest of all the categories of NRC licensees. As can be seen in Figure 14, the distribution does not compare favorably with that of the Reference Distribution resulting in Ω having a value of 3.54, which is higher than that of any other category. They did, however, avoid having any doses that exceeded 5 rems.

Licensees engaged in well logging activities did not experience as large a percentage of the collective dose contributed by doses exceeding 1.5 rems (Ω = 1.72) as did the Waste Disposal-Other licensees. They did, however, report nine workers as having annual doses greater than 5 rems, and with a collective dose of 1,748 man-rems, it is one of the six categories of licensees having a collective dose that exceeded 1,000 man-rems. Since the report "An

Figure 14.

Annual Dose Distributions of Other Byproduct Licensees 1975 and 1978



MAJOR CATEGORIES OF OTHER BYPRODUCT AND SYMBOL		EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1978 RATIO Ω	1975 RATIO Ω
WELL LOGGING	●	6,380	1,740	0.27	0.36	1.72	1.92
OTHER MEASURING SYSTEMS	×	24,720	650	0.03	0.10	0.66	0.24
WASTE DISPOSAL—BURIAL	○	18	3	0.17	0.20	0.00	2.75
WASTE DISPOSAL—OTHER	△	340	100	0.28	0.57	3.54	0.00
IRRADIATORS—TOTAL	+	3,630	145	0.04	0.15	0.73	0.00
OTHER BYPRODUCT*						Ω	
TOTAL 1978	■	37,670	2,730	0.07	0.19	1.44	
TOTAL 1975	□	39,345	4,631	0.12	0.31	1.70	

*THOSE GROUPED TOGETHER ON TABLE 1

Economic Study of the Radionuclides Industry"[10] discussed an industry segment called well logging that appears to closely correspond to the NRC program code 03110 for Well Logging licensees, the figures given in that document were compared with those reported by NRC licensees. Dividing the number of monitored individuals shown in the study (8,100) by two in order to roughly account for those monitored by Agreement State licensees, one obtains a figure of 4,050 monitored individuals. This compares more favorably with the NRC figures than did those for industrial radiographers.

From the plots in Figure 14, one can see that the dose distributions of the remaining major categories of Other Byproduct licensees agrees fairly well with that of the Reference Distribution. The plots for Other Measuring Systems and Irradiators-Total show that some individuals are likely to receive doses exceeding 1.5 rems; however, the extremely low average doses imply that many more people may be being monitored than would be required by current regulations. Plots of the distributions of composites of all the categories included in the group "Other Byproduct" (as shown in Table 1, page 9) are included in Figure 14 for comparison purposes. The shift upward in the composite plots of the 1978 data from that of the 1975 data is reflected in lower values of the average doses and Ω for 1978.

Figure 15 presents log-probability plots of composites (i.e., Source Material, Other SNM, Research Reactors, and Gas Cooled Reactors) of the data reported by the remaining categories of NRC licensees. Plots of

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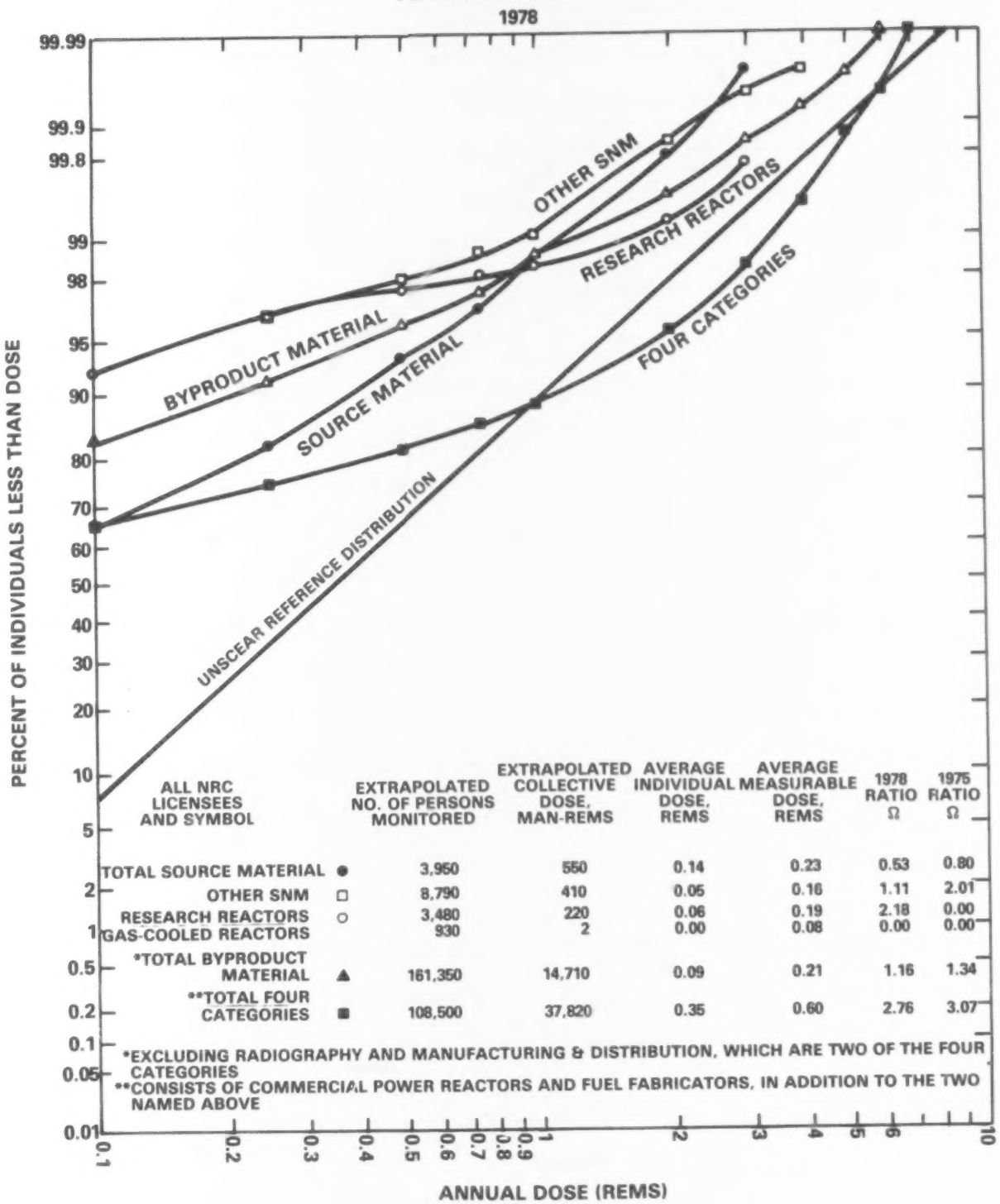
[10] Ibid, Footnote 2, page 7.

Figure 15

Annual Dose Distributions of
All NRC Licensees
1978



ALL NRC LICENSEES AND SYMBOL		EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1978 RATIO Ω	1975 RATIO Ω
TOTAL SOURCE MATERIAL	●	3,950	550	0.14	0.23	0.53	0.80
OTHER SNM	□	8,790	410	0.05	0.16	1.11	2.01
RESEARCH REACTORS	○	3,480	220	0.06	0.19	2.18	0.00
GAS-COOLED REACTORS		930	2	0.00	0.08	0.00	0.00
*TOTAL BYPRODUCT MATERIAL	▲	161,350	14,710	0.09	0.21	1.16	1.34
**TOTAL FOUR CATEGORIES	■	108,500	37,820	0.35	0.60	2.76	3.07

*EXCLUDING RADIOGRAPHY AND MANUFACTURING & DISTRIBUTION, WHICH ARE TWO OF THE FOUR CATEGORIES
**CONSISTS OF COMMERCIAL POWER REACTORS AND FUEL FABRICATORS, IN ADDITION TO THE TWO NAMED ABOVE

composites of the data reported by the categories of NRC licensees previously discussed are also shown for comparison. One can see that a curve for Gas Cooled Power Reactors does not appear on the graph because all individuals received doses that were less than 0.10 rem, the smallest value on the horizontal axis. The distribution of doses reported by Source Material licensees also compares quite favorably with the Reference Distribution, with the value of Ω being 0.53. From Table 2 (page 11), one can see that the value of Ω for each of the five categories of licensees in the Source Material grouping indicates that each one compares favorably with the Reference Distribution since Ω ranges between 0.00 and 0.79. The average measurable dose for workers in each of these categories is also fairly low, ranging from 0.00 rem to 0.24 rem. The distribution of the doses reported by the licensees in the Other SNM group, however, has a slightly larger portion of the collective dose contributed by doses greater than 1.5 rems (Ω = 1.11) than does the Reference Distribution, and the values of Ω for the ten categories comprising this group range from 0.00 to 2.93. The average measurable dose also varies considerably from one program code to another, with values ranging from 0.00 rem for SNM Storage Only licensees to 0.99 rem for Unencapsulated SNM licensees.

Figure 15 also shows that the distribution of doses reported by Research Reactor licensees is such that the percentage of the collective dose due to doses greater than 1.5 rems is higher than that of any of the five composite groups shown except that of the Four Categories of licensees that were previously required to report pursuant to §20.407. The average measurable dose, however, is 0.19 rem which is lower than that found for workers monitored by three of the five other groups. The Figure also indicates that the 108,500 individuals monitored by the Four Categories of licensees incurrred

a collective dose (37,850 man-rems) that is more than twice as large as that incurred by the 178,500 individuals estimated to have been monitored by the remaining types of NRC licensees. The average measurable dose calculated for the group of Four Categories is also about twice that of any of the other five groups but it remains less than 1 rem.

V. TERMINATION EXPOSURE DATA - 10 CFR §20.408

A. Terminations, 1969 - 1978

In 1969 NRC/AEC began requiring four categories* of its licensees to submit personal identification and exposure information upon the termination of each monitored person's employment or work assignment in the licensee's facility. Some 359,000 such records have been received for approximately 200,000 individuals who had terminated on or before December 31, 1978. The figures given for the number of reports and for the number of individuals are different because numerous individuals have terminated more than once over the years and because some individuals may have had external doses reported to more than one part of their body, as well as estimates of internal depositions of radioactive material, each of which is counted as one record. Table 11 provides a breakdown of this information for individuals terminating during each of the ten calendar years and shows that the number of such reports has increased each year. Since the majority of termination reports are now submitted by nuclear power utilities, the number of records and individuals that they reported is displayed separately.

B. Transient Workers per Calendar Quarter

One use that is being made of the information contained in the termination reports is the examination of the doses being received by short-term workers. Since nearly half of the termination reports indicated

*Operating nuclear power reactors; industrial radiographers; fuel processors, fabricators, and reprocessors; and manufacturers and distributors of specified quantities of byproduct material.

TABLE 11

TERMINATION REPORTS SUBMITTED TO THE NRC
1969 - 1978

YEAR	All Four Categories*		Power Reactor Licensees	
	Number of Termination Records	Number of Terminating Individuals	Number of Termination Records	Number of Terminating Individuals
1969	5,009	3,992	790	727
1970	8,069	6,069	2,126	1,908
1971	12,955	8,874	2,246	2,197
1972	15,685	10,353	4,997	3,888
1973	19,985	15,588	11,525	9,071
1974	30,389	21,499	16,946	11,603
1975	44,676	27,415	38,376	22,627
1976	70,230	40,079	63,593	35,294
1977	87,403	41,532	80,232	36,524
1978	94,960	43,182	84,360	36,649

* Commercial nuclear power reactors; industrial radiographers; fuel processors, fabricators, and reprocessors; manufacturers and distributors of specified quantities of byproduct materials.

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periods of exposure that were less than 90 days, it is possible that several thousand individuals could have been employed by two or more licensees during the same calendar quarter. Thus, by defining a "transient" worker to be a radiation worker who began and terminated employment at two different licensed facilities within one calendar quarter, one could examine the doses of those workers most likely to approach the quarterly limits without their present employer's knowledge since they move so rapidly from facility to facility.

Table 12 displays some of the information gathered from these termination reports that were submitted by the four categories of covered licensees. The number of these workers has increased more than twentyfold during the seven years 1972 through 1978, but now appears to be leveling off. This reflects the rate of growth of the nuclear power industry and its need for short-term workers. Thus, the figures obtained from reports submitted by power reactors are shown separately. One can also see that the average individual dose (which is close to being a quarterly dose for these workers) has tended to decrease during this time, and examinations of these records have revealed that some individuals have worked for as many as five different NRC licensees during one quarter. However, only one instance was found in which a worker may have slightly exceeded his quarterly limit of 3 rems as a result of his working at two different licensed facilities within one calendar quarter. That is not to say, however, that no other workers' doses have exceeded the quarterly limit because the records of those who were employed by a second licensee for a period spanning the end of a calendar quarter could not be examined in this manner, and the records of those employed by other than the four categories of NRC licensees are not submitted to the NRC.

TABLE 12

TRANSIENT WORKERS PER CALENDAR QUARTER

1972 - 1978

All Covered Licensees

Year	No. of Workers Terminated by 2 or more Licensees Within One Quarter	Collective Dose (Man-rems)	Average Individual Dose (Rem)
1972	69	63	0.91
1973	157	138	0.88
1974	332	170	0.51
1975	709	508	0.72
1976	1299	904	0.70
1977	1481	870	0.59
*1978	1570	720	0.46

Power Reactor Facilities

1972	57	57	1.00
1973	146	123	0.84
1974	285	158	0.55
1975	684	493	0.72
1976	1257	889	0.71
1977	1437	851	0.59
*1978	1500	680	0.45

*Data for 1978 may not be 100% complete.

C. Transient Workers per Calendar Year

Since the number of transient workers per calendar quarter comprise only a small percentage of the total number of individuals terminating each year, it was decided to change the parameters such that the records of more workers could be examined. This was done by selecting the records of all individuals who began and terminated two or more periods of employment with two different licensees within one calendar year and by summing each worker's whole body doses. An examination of this data would allow one to determine the average individual dose for these workers as well as to help determine the impact that the inclusion of these individuals in each of two or more licensees' annual reports had on the statistics obtained from the compilation of the annual reports submitted by groups of licensees. (This is one of the problems mentioned in Section II).

Since more than 95% of these workers are reported by nuclear power plants, only the records of these workers were examined. Table 13a presents the actual distribution of their doses as determined from the above-described termination reports and compares it to the distribution of the whole body doses as they would have been compiled from annual statistical reports submitted by the nuclear power facilities. One can see that in both 1977 and 1978 there were approximately 3,160 of these workers that worked at two or more nuclear power facilities during the year such that each one would have been counted as 2.5 workers in a compilation of these reports. In 1977 these workers incurred a collective dose of 3,776 man-rems which resulted in an average measurable dose of 1.29 rems rather than the 0.60 rem one would calculate from a compilation of the reports. In 1978 the collective dose

TABLE 13a

Actual and Compiled Dose Distributions of Transient Workers Per Calendar Year at Power Reactors

Type of Distribution and Year	Number of Individuals with Whole Body Doses in the Ranges (Rems)																		Total Workers	Total Man-Rems	Avg. Dose (Rems)	Avg. Meas. Dose (Rems)
	Less than Measurable	Meas'ble <0.10	0.10 0.25	0.25 0.50	0.50 0.75	0.75 1.00	1.00 2.00	2.00 3.00	3.00 4.00	4.00 5.00	5.00 6.00	6.00 7.00	7.00 8.00	8.00 9.00	9.00 10.00	10.00 11.00	11.00 12.00	>12.0				
ACTUAL DISTRIBUTION 1977	228	782	300	236	184	151	500	381	213	100	50	23	11	2					3,161	3,776	1.19	1.29
COMPILED DISTRIBUTION 1977	1,594	2,357	804	768	552	417	1,013	362	55	8	5								7,935	3,776	0.48	0.60
ACTUAL DISTRIBUTION 1978	302	869	316	286	166	144	462	293	159	106	46	15	2	0	1				3,167	3,193	1.01	1.11
COMPILED DISTRIBUTION 1978	2,025	2,402	916	780	495	377	859	246	51	11	0	2							8,164	3,193	0.39	0.52

TABLE 13b

Effects of Transient Workers on Annual Statistical Compilations

COMPILED STATISTICAL DISTRIBUTION --1977	27,671	15,523	6,750	5,179	3,300	2,500	6,174	2,838	1,130	569	141	66	36	21	6				71,904	32,731	0.46	0.74
CORRECTED STATISTICAL DISTRIBUTION --1977	26,305	13,948	6,246	4,647	2,932	2,234	5,661	2,857	1,288	661	286	89	47	23	6				67,230	33,193	0.49	0.81
COMPILED STATISTICAL DISTRIBUTION --1978	30,278	17,785	7,002	5,537	3,410	2,507	6,415	2,989	1,079	418	67	26	8	0	0	0	0	2	77,523	31,910	0.41	0.68
CORRECTED STATISTICAL DISTRIBUTION --1978	28,555	16,252	6,402	5,043	3,081	2,274	6,018	3,036	1,189	513	113	39	10	0	1	0	0	2	72,528	31,823	0.44	0.72

decreased to 3,193 man-rems such that the average measurable dose was found to be 1.11 rems rather than 0.52 rem. One can see that each year the actual distribution of the doses of these workers was such that there were about twice as many individuals incurring doses greater than 2 rems than would have been indicated in a compilation of the annual statistical reports. Although the number of these workers still seems to be increasing somewhat, it appears that their average dose is not.

Table 13b illustrates the impact that the multiple reporting of these transient workers had on the staff's compilations of the annual statistical reports for 1977 and 1978. Since each nuclear power facility reports the distribution of the doses received by workers while monitored by that particular facility during the year, one would expect a summation of these reports would result in individuals being counted several times in dose ranges lower than the range in which their total accumulated dose (the sum of the personnel monitoring results incurred at each facility during the year) would actually place them. Thus, while the total collective dose would remain about the same, the total number of workers and the average dose would be affected by this multiple reporting. This was found to be true. In each of the years 1977 and 1978, there were at least 3,300 too many workers indicated as having received measurable doses, and there were too few workers with doses in the higher ranges. For example, in 1977 the compiled annual reports indicated that 270 individuals received doses greater than 5.00 rems, while the corrected compilation indicated that there were at least 451 such workers. Although the number of these workers was much smaller in 1978, the compiled annual reports indicated 103 workers with doses exceeding 5.00 rems, while the

corrected compilation indicated some 165 such workers. However, the number of these transient workers receiving measurable doses is only about 3% or 4% of the total number receiving measurable doses during the year, and their impact on the statistics derived from compilations of the annual summary reports does not appear to be too great.

D. Age Distribution of Terminated Workers

Since some of the termination reports provide the birth date of the individual, one could examine these records and determine the age distribution of the workers terminating during the year. Table 14 indicates the results of such examinations for the years 1972 and 1978 for power reactor personnel and for non-power reactor personnel, which would be the individuals monitored by the remaining three types of NRC licensees. One can see that from 1972 to 1978 there was an increase in the percentage of younger workers terminating employment at power reactors, the largest increase being in the number of 20 to 24 year-olds which went from 9% to 14%. At non-power reactor facilities, there continued to be a considerably larger fraction of terminated workers less than 25 years-old than at power reactor facilities. The trend, however, appears to be an increase (going from 15% to 25%) in the proportion of terminated workers between the ages of 30 and 39 years and a decrease in most of the other age groups. Figure 16 graphically displays the age distribution of those workers terminating during 1978 for whom a birth date was reported.

TABLE 14

AGE DISTRIBUTION OF TERMINATING PERSONNEL

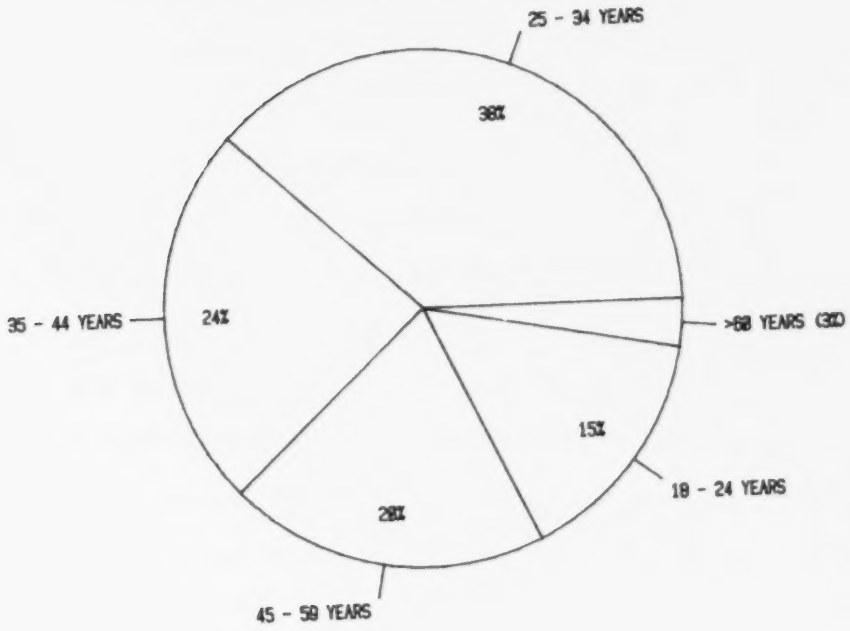
1972 & 1978

Age Range (Years)	Power Reactor Personnel				Non-power Reactor Personnel			
	1972		1978		1972		1978	
	No. of Terminating Workers	Percent of Total	No. of Terminating Workers	Percent of Total	No. of Terminating Workers	Percent of Total	No. of Terminating Workers	Percent of Total
18 - 19	58	2%	334	2%	272	5%	177	4%
20 - 24	258	9%	2,904	14%	1,353	25%	960	22%
25 - 29	458	17%	4,101	19%	1,012	19%	869	20%
30 - 34	460	17%	3,983	19%	485	9%	681	15%
35 - 39	386	14%	2,846	13%	301	6%	456	10%
40 - 44	365	13%	2,140	10%	309	6%	285	7%
45 - 49	307	11%	1,706	8%	310	6%	241	6%
50 - 54	240	9%	1,520	7%	503	9%	222	5%
55 - 59	145	5%	1,087	5%	479	9%	311	7%
> 60	97	3%	682	3%	345	6%	197	4%
Totals	2,774	100%	21,303	100%	5,369	100%	4,399	100%

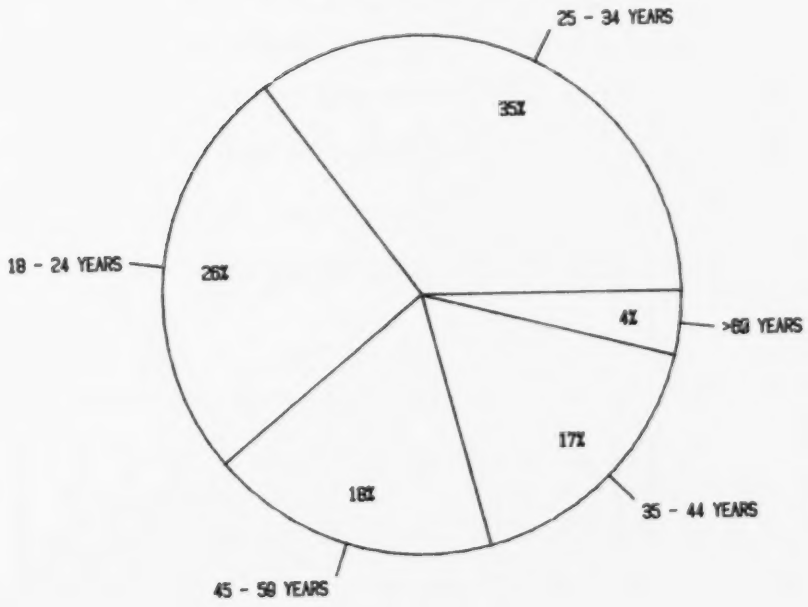
FIGURE 16

AGE DISTRIBUTION OF PERSONNEL TERMINATING IN 1978

TERMINATING POWER REACTOR PERSONNEL



TERMINATING NON-REACTOR PERSONNEL



VI. PERSONNEL OVEREXPOSURES - 10 CFR §20.403 AND 10 CFR §20.405

A. Types of Overexposures

One requirement of the above-referenced sections of Part 20, Title 10, Chapter 1, Code of Federal Regulations, is that all persons licensed by the NRC must submit reports of all incidents involving personnel radiation exposures that exceed certain levels. Based on the magnitude of the exposure, the reports may be placed into one of three categories:

1. Category A

   10 CFR §20.403(a) - Exposure of the whole body of any individual to 25 rems or more; exposure to the skin of the whole body of any individual to 150 rems or more; or exposure of the extremities (feet, ankles, hands or forearms) of any individual to 375 rems or more. The Commission must be notified immediately of these events.

2. Category B

   10 CFR §20.403(b) - Exposure of the whole body of any individual to 5 rems or more; exposure of the skin of the whole body of any individual to 30 rems or more; or exposure of the extremities to 75 rems or more. The Commission must be notified within 24 hours of these events.

3. Category C

   10 CFR §20.405 - Exposure of an individual to radiation or concentrations of radioactive material that exceeds any applicable

quarterly limit in Part 20 or in the licensee's license, but is less than the values given above. This includes reports of whole body exposures that exceed 1.25 rems, or that exceed 3 rems, as previously discussed on page 46. Reports of skin exposures that exceed 7.5 rems and extremity exposures that exceed 18.75 rems are included, and reports of exposures of individuals to concentrations in excess of the levels given in 10 CFR §20.103 and Appendix B, usually fall into this category as well. These reports must be submitted to the Commission within 30 days of the occurrence.

A short description of the six incidents occurring in 1978 that resulted in exposures of the magnitude indicated in Category A or B is given in Appendix B to this report.

B. Summary of Overexposures

Table 15 summarizes all of the occupational overexposures to external sources of radiation as reported by Commission licensees pursuant to §20.403 and §20.405 during each of the years 1977 and 1978. It shows the number of individuals that incurred various types of overexposures while employed by one of several types of licensees. Most of the overexposures included in the "All Others" category come from test reactors, universities, and facilities with large irradiator sources. In 1978 the total number of individuals reported as being overexposed was 27, a considerable decrease from the number (62) reported in 1977. In 1978 the highest whole body overexposure was 27.3 rems, while in 1977 it was 220 rems. The number and magnitude of overexposures reported by industrial radiographers have been decreasing for the last two years.

TABLE 15

PERSONNEL OVEREXPOSURES TO EXTERNAL RADIATION
1977 and 1978

LICENSE CATEGORY	YEAR	Persons and Doses	TYPE OF OVEREXPOSURE								
			Whole Body			Skin			Extremity		
			>1.25<5 rems	>5<25 rems	>25 rems	>7.5<30 rems	>30<150 rems	>150 rems	>18.75<75 rems	>75<375 rems	>375 rems
Industrial Radiography	1978	No. of Persons	4	1						1	
		Sum of Doses (Rems)	15.34	21.6						150	
Power Reactor Facilities	1978	No. of Persons	6	2[a]	1						
		Sum of Doses (Rems)	21.26	22.59	27.3						
Medical Facilities	1978	No. of Persons	5	2							
		Sum of Doses (Rems)	13.42	29.32							
Marketing and Manuf. & Dist.	1978	No. of Persons							1		
		Sum of Doses (Rems)							29.78		
All Others	1978	No. of Persons	1			2			1		
		Sum of Doses (Rems)	1.32			18.18			19.29		
Totals	1978	No. of Persons	16	5	1	2			2	1	
		Sum of Doses (Rems)	51.34	73.51	27.3	18.18			49.07	150	
Industrial Radiography	1977	No. of Persons	7	2[b]							1
		Sum of Doses (Rems)	23.73	23.2							630
Power Reactor Facilities	1977	No. of Persons	28								
		Sum of Doses (Rems)	55.98								
Medical Facilities	1977	No. of Persons	4						3		
		Sum of Doses (Rems)	7.99						71.30		
Marketing and Manuf. & Dist.	1977	No. of Persons	2			3[c]			6		
		Sum of Doses (Rems)	3.59			39.95			122.78		
All Others	1977	No. of Persons	4		1				1		
		Sum of Doses (Rems)	7.35		220				30.0		
Totals	1977	No. of Persons	45	2	1	3			10		1
		Sum of Doses (Rems)	98.64	23.2	220	39.95			224.08		630

[a] One 19-year old worker received a dose of 5.49 rems which exceed his maximum permissable annual dose of 5 rems. This reported pursant to 10 CFR 20.405.
[b] One of these persons simultaneously received an extremity overexposure of 18.00 rems which is not shown in the Table.
[c] One of these persons simultaneously received an extremity overexposure of 26.38 rems which is not shown in the Table.

The number of reported personnel exposures to airborne concentrations of radioactive materials in excess of applicable limits was about the same as that reported in 1977. However, there was only one instance in which the estimated intake of radioactive material exceeded the quarterly intake limit, equivalent to exposure for 520 hours at the maximum permissible concentrations (MPC-hours) compared to four cases in 1977. None of these cases exceeded an annual intake limit, equivalent to 2000 MPC-hours.

APPENDIX A

Tables taken from NUREG-0419

"Occupational Radiation Exposure at NRC-Licensed Facilities - 1975"

APPENDIX A

TABLE 1
SUMMARY OF 1975 VOLUNTARY MONITORING DATA

Category	Fraction Reporting	Number of Licensees Who Monitored	Number of Individuals Monitored	Average Dose, Rems	Number of Individuals With Measurable Doses	Average Measurable Dose, Rems	Collective Dose Reported, Man-Rems	Average Collective Dose Per Licensee, Man-Rems	Extrapolated Number of Individuals Monitored[a]	Extrapolated Collective Dose,[b] Man-Rems
Byproduct Material										
Academic Broad	8/22	8	1,927	0.01	207	0.10	21.11	2.64	5,300	60
Academic Other	79/476	54	3,609	0.03	970	0.11	103.54	1.31	21,700	620
Instit. Broad Med.	40/94	40	14,228	0.07	5,354	0.18	975.98	24.40	33,400	2,290
Instit. Other Med.	345/1355	342	9,643	0.18	6,180	0.28	1,750.18	5.07	37,900	6,870
Private Practice	73/701	64	486	0.28	392	0.35	137.31	1.88	4,700	1,320
Teletherapy	46/470	46	1,716	0.15	927	0.29	264.73	5.76	17,500	2,700
Other Medical	17/103	14	356	0.13	168	0.27	46.01	2.71	2,200	280
Radiopharm. Dist.	3/30	3	25	0.08	. 9	0.23	2.10	0.70	250	20
Pacemakers Instit.	0/8									
Pacemakers Individ.	0/4									
Well Logging	14/63	14	1,514	0.44	1,328	0.50	666.11	47.58	6,800	3,000
Other Meas. Systems	278/2109	121	2,594	0.06	1,053	0.14	147.31	0.53	19,700	1,120
Marketing Broad	11/62	8	703	0.05	140	0.26	36.31	3.30	4,000	200
Marketing Other	48/244	39	1,195	0.07	293	0.28	82.39	1.72	6,100	420
Gen. Lic. Dist.	2/57	1	8	0.13	8	0.13	1.05	0.53	230	30
Exempt Quant. Dist.	4/44	2	103	0.03	50	0.07	3.58	0.90	1,130	40
Exempt Watch Dist.	5/64	1	11	0.06	11	0.06	0.68	0.14	140	10
Other Exempt Dist.	7/84	6	232	0.01	49	0.06	3.03	0.43	2,790	35
Nuclear Laundry	1/5	1	4	0.00					20	
Leak Test	3/28	2	6	0.06	4	0.08	0.33	0.11	60	3
Waste Disposal - Burial	4/4	4	65	1.24	64	1.26	80.63	20.16	65	81
Waste Disposal - Other	2/9	2	8	0.006	1	0.05	0.05	0.03	40	0.2
Power Sources	0/1									
Irradiator <10,000 Ci	3/164	2	26	0.03	5	0.17	0.83	0.28	1,420	50
Irradiator >10,000 Ci	3/55	3	134	0.003	1	0.38	0.38	0.13	2,460	7
R & D Broad	21/83	20	5,802	0.03	1,250	0.14	180.36	8.59	22,900	710
R & D Other	88/435	69	2,298	0.02	724	0.08	54.30	0.62	11,400	270
Civil Defense	10/129	8	682	0.04	553	0.05	28.36	2.84	8,800	370
Byproduct Export	0/56									
Transport Large Qty.	0/3									
Transport Type B	1/1	1	190	0.16	110	0.28	30.47	30.47	190	30
Source Material										
U Mills	7/17	7	437	0.38	404	0.41	166.05	23.72	1,060	400
Other U <150 kg	3/58	2	19	0.00					370	
Other U >150 Kg	8/320	8	149	0.12	108	0.17	18.56	2.32	5,960	740
UF_6 Production	2/2	2	522	0.14	330	0.22	73.56	36.78	520	70
Source Mtl. Export	1/48	1	50	0.02	22	0.05	1.10	1.10	2,400	50
Source Mtl. Import	0/4									

Continued....

APPENDIX A (continued)

Table 1 (Continued)

Category	Fraction Reporting	Number of Licensees Who Monitored	Number of Individuals Monitored	Average Dose, Rems	Number of Individuals With Measurable Doses	Average Measurable Dose, Rems	Collective Dose Reported, Man-Rems	Average Collective Dose Per Licensee, Man-Rems	Extrapolated Number of Individuals Monitored[a]	Extrapolated Collective Dose,[b] Man-Rems
Special Nuclear Material										
Other Pu Uses R&D	0/3									
Other U Uses R&D	1/22	1	154	0.02	15	0.17	2.53	2.53	3,390	60
Unencapsulated SNM	2/29	2	204	0.11	14	1.54	21.59	10.80	2,960	310
Neutron Sources	18/308	9	247	0.02	45	0.09	4.08	0.23	4,230	70
Power Sources	0/4									
Other SNM Sources	5/60	4	203	0.05	77	0.13	9.79	1.96	2,440	120
Pacemakers Instit.	0/91									
Pacemakers Individ.	1/7	0								
U Sources	3/48	3	408	0.001	8	0.07	0.53	0.18	6,530	8
Fuel Storage	1/10	1	13	0.69	13	0.69	9.00	9.00	130	90
SNM Storage Only	1/2	1	4	0.01	1	0.05	0.05	0.05	8	0.1
SNM Import	0/12									
SNM Export	1/156	1	6	0.00	0				940	
Transport Irr. Fuel	0/2									
Transport Unirr. Fuel	0/2									
Transport Large Quant.	0/3									
Test Reactors	1/2	1	7	0.05	7	0.05	0.35	0.35	14	0.7
Research Reactors	3/66	3	152	0.12	120	0.16	18.98	6.33	3,350	420
[c]Power Reactors	54/54	54	54,763	0.39	28,034	0.76	21,269.72	393.88	54,763	21,270
[c]Radiographers	291/320	291	9,178	0.31	4,693	0.60	2,795.94	9.61	10,100	3,080
[c]Fuel Proc & Reproc	24/24	24	11,614	0.27	5,602	0.57	3,175.30	132.30	11,614	3,175
[d]Manufacture & Dist.	19/23	19	3,367	0.35	1,859	0.64	1,188.17	62.54	4,100	1,440

[a](Extrapolated Number of Individuals Monitored) = (Individuals Monitored)/(Fraction Reporting)

[b](Extrapolated Collective Dose) = (Reported Collective Dose)/(Fraction Reporting)

Note: The effect on these extrapolations of the licensees who did not monitor is canceled by appearance in both the numerator and denominator of the Fraction Reporting.

[c]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

[d]Subset of "Marketing Broad" and "Marketing Other" meeting the criteria in §20.407(a)(4) of 10 CFR Part 20.

APPENDIX A (continued)

TABLE 2
1975 MONITORING DATA BY LICENSEE FUNCTIONAL GROUP
(EXTRAPOLATED TO ALL LICENSEES IN GROUP)

Licensee Functional Grouping	Number of Individuals Monitored	Collective Dose, Man-Rems	Average Dose Per Individual, Rems
Academic	27,000	680	0.03
Medical	95,700	13,500	0.14
Marketing	14,600	760	0.05
R & D	34,300	980	0.03
Byproduct Material	211,200	20,540	0.10
Source Material	10,300	1,260	0.12
Special Nuclear Material	20,630	660	0.03
Research & Test Reactors	3,400	420	0.12
Power Reactors[a]	54,760	21,270	0.39
Industrial Radiographers[a]	10,100	3,080	0.31
Fuel Processing & Reprocessing[a]	11,610	3,175	0.27
Manufacturing & Distribution[b]	4,100	1,440	0.35

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

[b]Subset of "Marketing Broad" and "Marketing Other" meeting the criteria in §20.407(a)(4) of 10 CFR Part 20.

APPENDIX A (continued)

TABLE 3
DISTRIBUTION OF ESTIMATED DOSES - 1975 VOLUNTARY DATA

Category of Licensee	Total No. Monitored	Exposure Ranges (Rems)																
		Less Than Measurable	Meas'ble 0.10	0.10 0.25	0.25 0.50	0.50 0.75	0.75 1.0	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12+
Byproduct Material																			
Academic Broad	1927	1720	157	35	11	2	2												
Academic Other	3609	2639	781	127	34	13	5	8	2										
Instit. Broad Med.	14228	8874	3451	1016	502	160	85	106	25	4	2	1	2						
Instit. Other Med.	9643	3463	3094	1402	834	361	190	200	52	22	16	2	4	0	1	0	2		
Private Practice	486	94	166	90	67	27	12	19	4	3	0	2							
Teletherapy	1716	789	539	158	111	46	16	30	14	5	6								
Other Medical	356	188	101	24	17	12	5	6	2	0	1								
Radiopharm. Dist.	25	16	3	4	0	2													
Pacemakers Instit.																			
Pacemakers Individ.																			
Well Logging	1514	186	387	315	249	128	82	117	23	19	4	1	1	1	0	1			
Other Meas. Systems	2594	1541	704	197	103	36	8	3	2										
Marketing Broad	703	563	77	29	16	5	2	11											
Marketing Other	1195	902	177	58	21	11	7	12	3	1	3								
Gen. Lic. Dist.	8	0	6	0	2														
Exempt Quant. Dist.	103	53	45	4	0	1													
Exempt Watch Dist.	11	0	10	1															
Other Exempt Dist.	232	183	46	2	1														
Nuclear Laundry	4	4																	
Leak Test	6	2	3	1															
Waste Disposal - Burial	65	1	9	11	8	6	4	8	9	7	2								
Waste Disposal - Other	8	7	1																
Power Sources																			
Irradiator <10,000 Ci	26	21	4	0	0	1													
Irradiator >10,000 Ci	134	133	0	0	1														
R & D Broad	5802	4552	1025	117	49	18	12	14	6	8	1								
R & D Other	2298	1574	651	50	16	4	0	3											
Civil Defense	682	129	551	1	0	1													
Byproduct Export																			
Transport Large Quant.																			
Transport Type B	190	80	43	21	25	15	5	1											
Source Material																			
U Mills	437	33	123	88	86	44	22	38	2	1									
Other U <150 kg	19	19																	
Other U >150 kg	149	41	78	13	10	0	3	4											
UF_6 Production	522	192	118	128	49	20	13	2											
Source Mtl. Export	50	28	22																
Source Mtl. Import																			

Continued...

APPENDIX A (continued)

Table 3 (Continued)

Category of Licensee	Total No. Monitored	Exposure Ranges (Rems)																	
		Less Than Measurable	Meas'ble 0.10	0.10 0.25	0.25 0.50	0.50 0.75	0.75 1.0	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12+
Special Nuclear Material																			
Other Pu Uses R&D																			
Other U Uses R&D	154	139	4	9	2														
Unencapsulated SNM	204	190	3	1	1	0	1	3	2	3									
Neutron Sources	247	202	32	12	1														
Power Sources																			
Other SNM Sources	203	126	59	9	5	3	0	1											
Pacemakers Instit.																			
Pacemakers Individ.																			
U. Sources	408	400	7	1															
Fuel Storage	13	0	0	0	2	8	2	1											
SNM Storage Only	4	3	1																
SNM Import																			
SNM Export	6	6																	
Transport Irr. Fuel																			
Transport Unirr. Fuel																			
Transport Large Quant.																			
Test Reactors	7	0	7																
Research Reactors	152	32	39	73	4	3	1												
[a]Power Reactors	54763	26729	10606	4081	2948	1778	1384	3982	1873	692	[illegible]	169	60	24	12	0	1		
[a]Radiographers	9178	4485	1811	813	614	346	263	538	171	64	35	21	8	1	3	1	2	1	1
[a]Fuel Proc & Reproc	11614	6012	2019	1115	1029	440	253	393	157	77	40	30	11	9	14	15			
[b]Manufacture & Dist.	3367	1508	644	532	214	88	67	140	65	43	39	11	12	3	0	1			

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

[b]Subset of "Marketing Broad" and "Marketing Other" meeting the criteria in §20.407(a)(4) of 10 CFR Part 20.

APPENDIX A (continued)

TABLE 4
EXTRAPOLATED TOTAL COLLECTIVE DOSE BY CATEGORY OF LICENSEE (MAN-REMS)
1975

[a]Power Reactors	21,270
Instit. Other Medical	6,880
[a]Fuel Proc. & Reproc.	3,175
[a]Radiographers	3,080
Well Logging	3,000
Teletherapy	2,700
Instit. Broad Medical	2,290
[a]Manufacture & Dist.	1,440
Private Practice	1,320
Other Meas. Systems	1,120
Other U >150 kg	740
R & D Broad	710
Academic Other	620
Marketing Other	420
Research Reactors	420
U Mills	400
Civil Defense	370
Unencapsulated SNM	310
Other Medical	280
R & D Other	270
Marketing Broad	200
Other SNM Sources	120
Fuel Storage	90
Waste Disposal - Burial	81
UF_6 Production	70
Neutron Sources	70
Academic Broad	60
Other U Uses R & D	60
Source Mtl. Export	50
Irradiator <10,000 Ci	50
Exempt Quant. Dist.	40
Other Exempt Dist.	35
Gen. Lic. Dist.	30
Transport Type B	30
Radiopharm. Dist.	20
Exempt Watch Dist.	10
U Sources	8
Irradiator >10,000 Ci	7
Leak Test	3
Test Reactors	0.7
Waste Disposal Other	0.2
SNM Storage Only	0.1

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

APPENDIX A (continued)

TABLE 5
AVERAGE COLLECTIVE DOSE PER LICENSEE IN A GIVEN CATEGORY
(MAN-REMS)
1975

[a]Power Reactors	394
[a]Fuel Proc. & Reproc.	132
[a]Manufacture & Dist.	62.5
Well Logging	47.6
UF_6 Production	36.8
Transport Type B	30.5
Instit. Broad Medical	24.4
U Mills	23.7
Waste Disposal - Burial	20.2
Unencapsulated SNM	10.8
[a]Radiographers	9.6
Fuel Storage	9.0
R & D Broad	8.6
Research Reactors	6.3
Teletherapy	5.8
Instit. Other Medical	5.1
Marketing Broad	3.3
Civil Defense	2.8
Other Medical	2.7
Academic Broad	2.6
Other U Uses R & D	2.5
Other U >150 kg	2.3
Other SNM Sources	2.0
Private Practice	1.9
Marketing Other	1.7
Academic Other	1.3
Source Mtl. Export	1.1
Exempt Quant. Dist.	.9
Radiopharm. Dist.	.7
R & D Other	.6
Other Meas. Systems	.5
Gen. Lic. Dist.	.5
Other Exempt Dist.	.4
Test Reactors	.4
Irradiator <10,000 Ci	.3
Neutron Sources	.2
U Sources	.2
Exempt Watch Dist.	.1
Irradiator >10,000 Ci	.1
Leak Test	.1
SNM Storage Only	.1
Waste Disposal Other	.03

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

APPENDIX A (continued)

TABLE 6
AVERAGE INDIVIDUAL DOSE BY CATEGORY
1975

Category of Licensee	Average Dose, Rems	Average Measurable Dose, Rems
Waste Disposal - Burial	1.24	1.26
Fuel Storage	0.69	0.69
Well Logging	0.44	0.50
[a]Power Reactors	0.39	0.76
U Mills	0.38	0.41
[a]Manufacture & Dist.	0.35	0.64
[a]Radiographers	0.31	0.60
Private Practice	0.28	0.35
[a]Fuel Proc. & Reproc.	0.27	0.57
Instit. Other Medical	0.18	0.28
Transport Type B	0.16	0.28
Teletherapy	0.15	0.29
UF_6 Production	0.14	0.22
Other Medical	0.13	0.27
Gen. Lic. Dist.	0.13	0.13
Research Reactors	0.13	0.16
Other U >150 kg	0.12	0.17
Unencapsulated SNM	0.11	1.54
Radiopharm. Dist.	0.08	0.23
Instit. Broad Medical	0.07	0.18
Marketing Other	0.07	0.28
Other Meas. Systems	0.06	0.14
Exempt Watch Dist.	0.06	0.06
Leak Test	0.06	0.08
Marketing Broad	0.05	0.26
Other SNM Sources	0.05	0.13
Test Reactors	0.05	0.05
Civil Defense	0.04	0.05
Exempt Quant. Dist.	0.03	0.07
Academic Other	0.03	0.11
Irradiator <10,000 Ci	0.03	0.17
R & D Broad	0.03	0.14
R & D Other	0.02	0.08
Source Mtl. Export	0.02	0.05
Other U Uses R & D	0.02	0.17
Neutron Sources	0.02	0.09
Academic Broad	0.01	0.10
Other Exempt Dist.	0.01	0.06
SNM Storage Only	0.01	0.05
Waste Disposal Other	0.006	0.05
Irradiator >10,000 Ci	0.003	0.38
U Sources	0.001	0.07

[a]Currently reporting pursuant to §20.407 of 10 CFR Part 20.

APPENDIX A (continued)

TABLE 7
AVERAGE INDIVIDUAL DOSE, EXTRAPOLATED COLLECTIVE DOSE, AND Ω
1975 VOLUNTARY DATA

Category Of Licensee	Average Individual Dose ($\bar{D}$), Rems	Extrapolated Collective Dose (S), Man-Rems	Ω[a]	Ω[b]
Byproduct Material				
Academic Broad	0.01	60	0.0	0.0
Academic Other	0.03	620	0.34	0.52
Instit. Broad Med	0.07	2,290	0.61	0.93
Instit. Other Med	0.18	6,880	0.92	1.41
Private Practice	0.28	1,320	1.08	1.66
Teletherapy	0.15	2,700	1.24	1.90
Other Medical	0.13	280	0.98	1.50
Radiopharm. Dist.	0.08	20	0.0	0.0
Pacemakers Instit.				
Pacemakers Individ.				
Well Logging	0.44	3,000	1.25	1.92
Other Meas. Systems	0.06	1,120	0.16	0.24
Marketing Broad	0.05	200	0.73	1.12
Marketing Other	0.07	420	1.32	2.02
Gen. Lic. Dist.	0.13	30	0.0	0.0
Exempt Quant. Dist.	0.03	40	0.0	0.0
Exempt Watch Dist.	0.06	10	0.0	0.0
Other Exempt Dist.	0.01	35	0.0	0.0
Nuclear Laundry	0.00			
Leak Test	0.06	3	0.0	0.0
Waste Disposal Burial	1.24	81	2.48	3.80
Waste Disposal Other	0.006	0.2	0.0	0.0
Power Sources				
Irradiator <10,000 Ci	0.03	50	0.0	0.0
Irradiator >10,000 Ci	0.003	7	0.0	0.0
R & D Broad	0.03	710	1.04	1.59
R & D Other	0.02	270	0.13	0.20
Civil Defense	0.04	370	0.0	0.0
Byproduct Export				
Transport Large Quant.				
Transport Type B	0.16	30	0.08	0.12
Source Material				
U Mills	0.38	400	0.72	1.10
Other U <150 kg	0.00			
Other U >150 kg	0.12	740	0.52	0.80
UF_6 Production	0.14	70	0.07	0.11
Source Mtl. Export	0.02	50	0.0	0.0
Source Mtl. Import				

Continued...

[a] Ω, a dimensionless quantity, is the ratio of the fraction of the collective dose due to annual doses above 1.5 rads for the observed distribution to the fraction for the UNSCEAR reference distribution (Ref. 4). For any observed distribution $\Omega = 3.23S_{1.5}/S$.

[b] Due to the correction previously noted in Section II.A.1, the values of Ω were recalculated in accordance with the equation $\Omega = 4.95S_{1.5}/S$.

APPENDIX A (continued)

TABLE 7 (Continued)

Category Of Licensee	Average Individual Dose ($\bar{D}$), Rems	Extrapolated Collective Dose (S), Man-Rems	Ω[a]	Ω[b]
Special Nuclear Material				
Other Pu Uses R&D	0.02	60	0.0	0.0
Other U Uses R&D	0.11	310	2.66	4.08
Unencapsulated SNM	0.02	70	0.0	0.0
Neutron Sources				
Power Sources	0.05	120	0.25	0.38
Other SNM Sources				
Pacemakers Instit.				
Pacemakers Individ.	0.001	8	0.0	0.0
U Sources	0.69	90	0.27	0.41
Fuel Storage	0.01	0.1	0.0	0.0
SNM Storage Only				
SNM Import	0.00			
SNM Export				
Transport Irr. Fuel				
Transport Unirr. Fuel				
Transport Large Quant.				
.				
Test Reactors	0.05	0.7	0.0	0.0
Research Reactors	0.12	420	0.0	0.0

[a] Ω, a dimensionless quantity, is the ratio of the fraction of the collective dose due to annual doses above 1.5 rads for the observed distribution to the fraction for the UNSCEAR reference distribution (Ref. 4). For any observed distribution $\Omega = 3.23S_{1.5}/S$.

[b] Due to the correction previously noted in Section II.A.1, the values of Ω were recalculated in accordance with the equation $\Omega = 4.95S_{1.5}/S$.

APPENDIX B

Summary of Overexposures Reported Pursuant to 10 CFR §20.403

1978

APPENDIX B

SUMMARY OF OVEREXPOSURES REPORTED PURSUANT TO 10 CFR §20.403

1978

Medical Institution - License Number 29-05013-01

On January 25, 1978, a nuclear medicine technician spilled 0.060 curies of radioactive technetium on the floor. The technician was alone in the hot lab, and she cleaned it up with towels. She changed her clothes, and no radioactive material was found on her. Her film dosimeter was processed, and the results indicated that a whole body dose of 6.76 rems had been received during the quarter.

The licensee increased its efforts to develop better procedures and properly train personnel. An independent consultant was retained, and a radioisotopes committee was formed to review the nuclear medicine program.

Nuclear Power Facility - License Number NPF-1

On April 5, 1978, two radiation protection technicians received whole body doses of 27.3 and 17.1 rems. They were conducting a radiation survey in the area of the fuel transfer tube. When they came into contact with a short, nearly inaccessible section of the transfer tube that was unshielded, they did not recognize it as such. They remained there while spent fuel was transferred from the refueling cavity in the containment building to the spent fuel pool.

Following identification of the possible overexposures, a guard was posted to prevent access to the area, and fuel transfer was halted until a wall and a steel door were installed the following day. For further details, see NUREG-0090, Vol. 1, No. 2, "Report to Congress on Abnormal Occurrences," September 1978.

Industrial Radiography - License Number 47-16182-01

On June 5, 1978, after completing a radiograph, the radiographer tried to return the source to its shielded position in the exposure device. When he surveyed the device, the survey meter indicated a relatively high exposure rate when held close to the device, as well as at a distance of 30 feet. The radiographer then thought that the meter was malfunctioning and proceeded to unscrew the source guide tube. When he saw the drive cable, he realized that the source was not shielded and immediately left. He was estimated to have received a dose of 150 rems to his left hand and 2.9 rems to the lens of his eyes.

The radiographer was reprimanded for not following the company's Operating and Emergency Procedures and was restricted from working in radiation areas for a time. The company also began providing radiographic personnel with spare survey meters to use as backup equipment.

Industrial Radiography - License Number 22-01376-02

On November 15, 1978, while radiographing pipe welds at a power plant under construction, a radiographer thought he had completely retracted the source into its shielded position in the exposure device. He hastily surveyed

and prepared the pipe and film for the next radiograph. When he started to crank the source out, he realized that the 50 curie iridium-192 source had not been shielded. He locked the exposure device and notified his supervisor. It was estimated that he received a whole body dose of 21.6 rems.

The major cause of the incident was the radiographer's failure to conduct a complete and proper survey of the exposure device and source tube. Additional training in conducting surveys was given to all radiographic personnel.

Medical Institution - License Number 12-01081-01

The results of the routine processing of a nuclear medicine technician's whole body dosimeter indicated that a whole body dose of 22.56 rems could have been received during the fourth quarter of 1978. The technician's duties had been limited to the dispensing of iodine-131 capsules, the eluting of 1.5 curie technetium-99m generators, the administration of the technetium-99m diagnostic doses to patients, and the subsequent scanning of those patients. The technician, who frequently worked alone, could not recall any incident or unusual occurrence to which the high exposure could be attributed.

While there were some indications that a spill of material may have occurred which could have contaminated her dosimeter, her denial of such an occurrence precluded the estimation of the dose she could have received from it. Therefore, the recorded dose was assigned to the technician, and she was removed from work in radiation areas. The licensee had failed to ensure that proper surveys and wipe tests were conducted.

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This report summarizes the information reported for calendar year 1978 by all NRC licensees to the Commission's centralized repository of personnel occupational radiation exposure information. The bulk of the information in the report is derived from annual reports that were required to be submitted by all NRC licensees pursuant to 10CFR 20.407. Previously only certain categories - commercial nuclear power reactors, industrial radiographers, fuel fabricators and processors and commercial distributors of byproduct materials - of NRC licensees had submitted such reports. The requirement of 10 CFR 20.408 for the submission of termination reports continued to apply to only these four categories, and some analysis of the data contained in these reports is also presented. A brief description of personnel overexposures reported by NRC licensees is included as well.

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